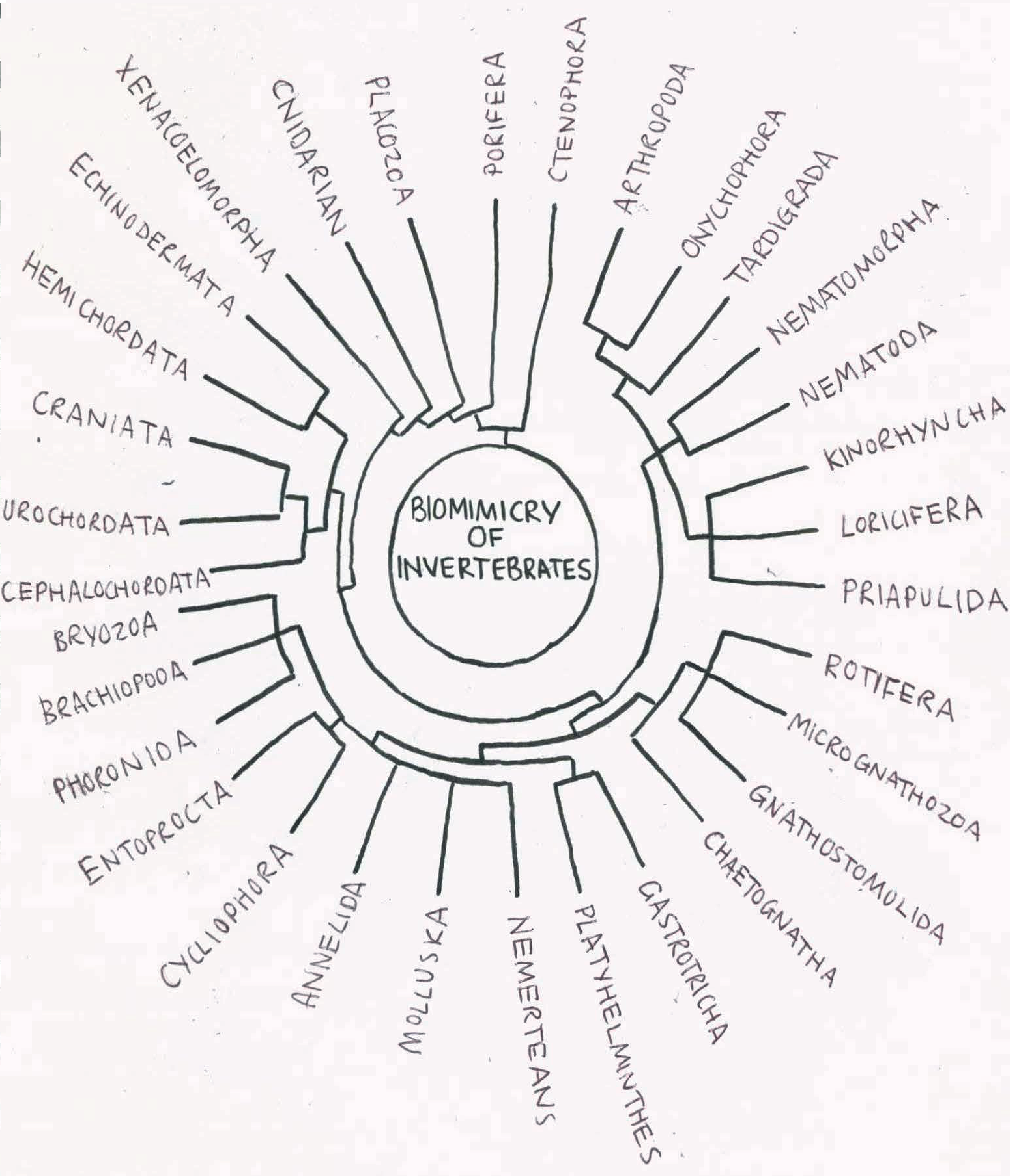
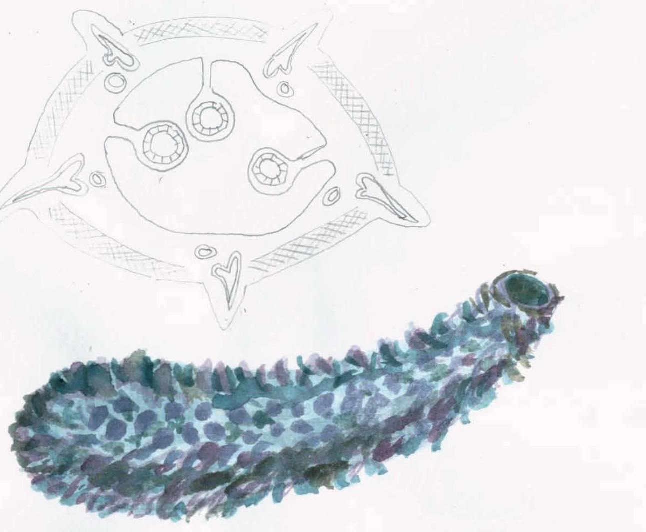
INVERTEBRATES
FINAL PROJECT
BY GEMMA SHEPHERD



BIOMIMICRY OF INVERTEBRATES

BY GEMMA SHEPHERD

ECHINODERMATA HOLOTHUROIDEA Sea cucumber



RIGIDITY & FLEXIBILITY
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SMART POLYMER
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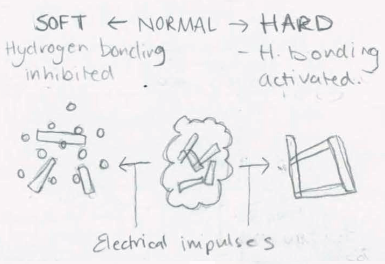
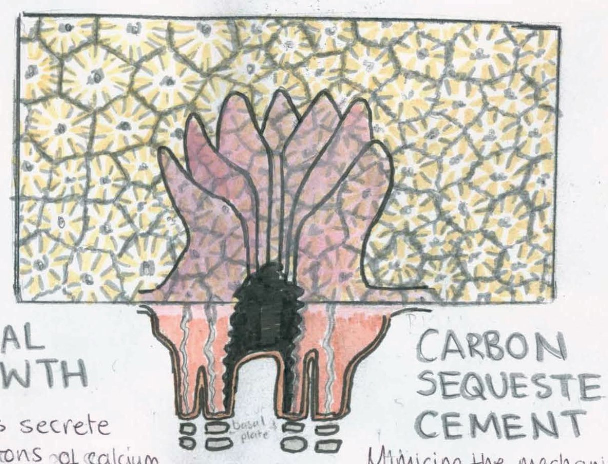


CNIDARIAN ANTHOZOA Stony corals



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Mimicing the mechanism by which corals build thier skeletons could transform th cement industry, which is currently responsible for 8% of total CO_2 emissions. The cement company Calcera now makes cement by dissolving waste CO_2 from power plants in seawater to form carbonate ions (CO_3^{2-}) which mix with calcium in the ocean to form a solid cement alternative whilst sequestering CO_2.

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PORIFERA HEXACTINELLIDA Glass sponge

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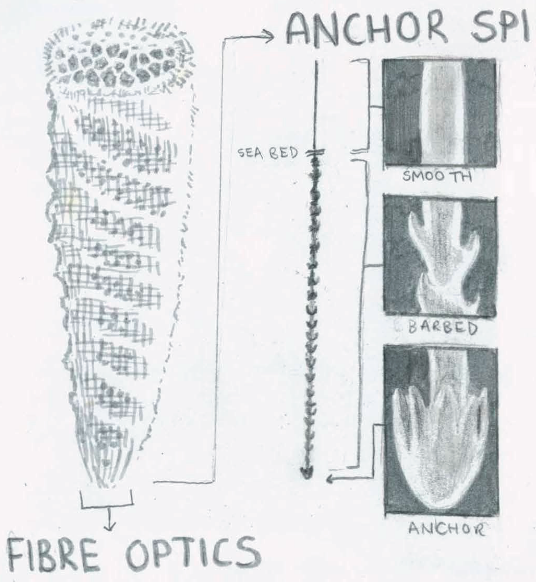

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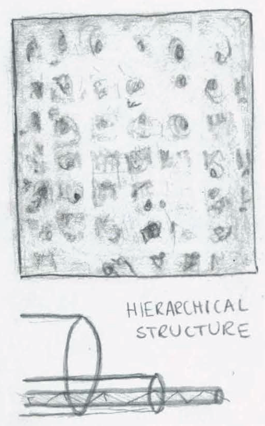

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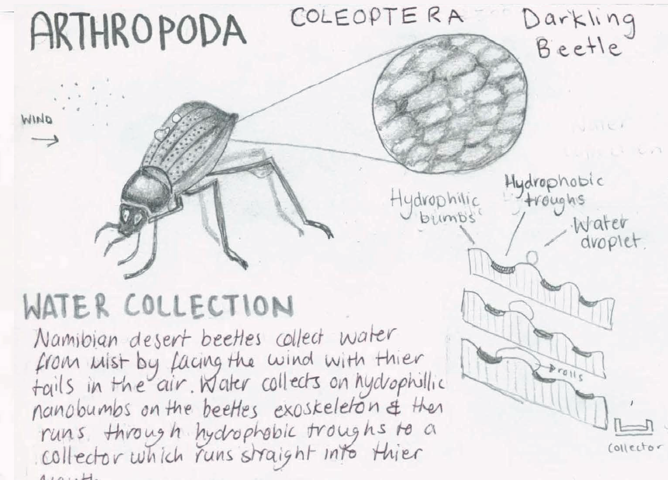

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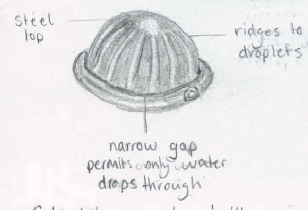

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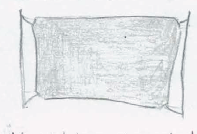

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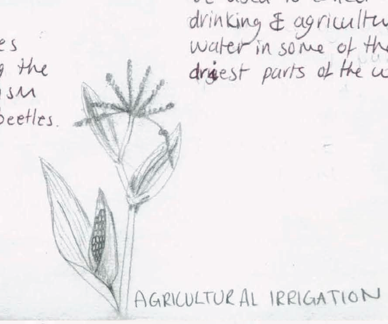

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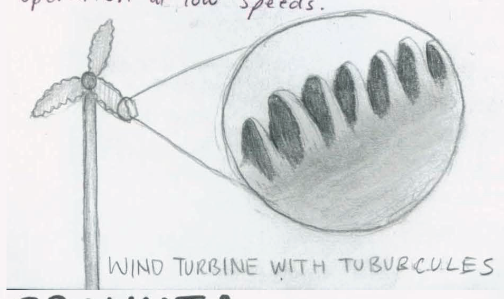

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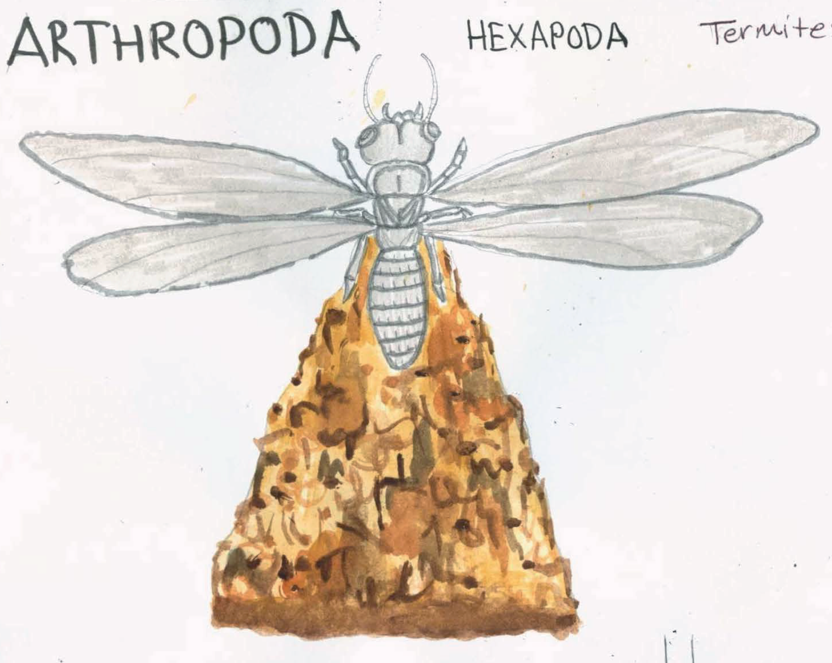

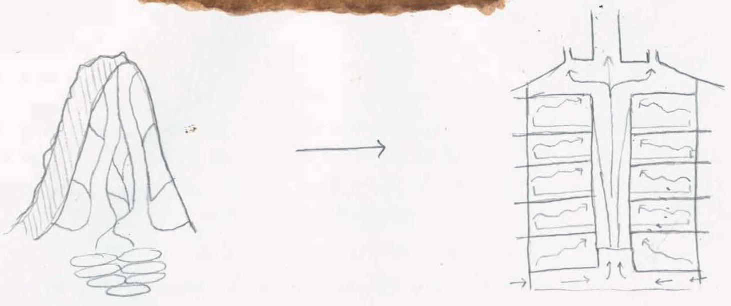

TEMPERATURE REGULATION
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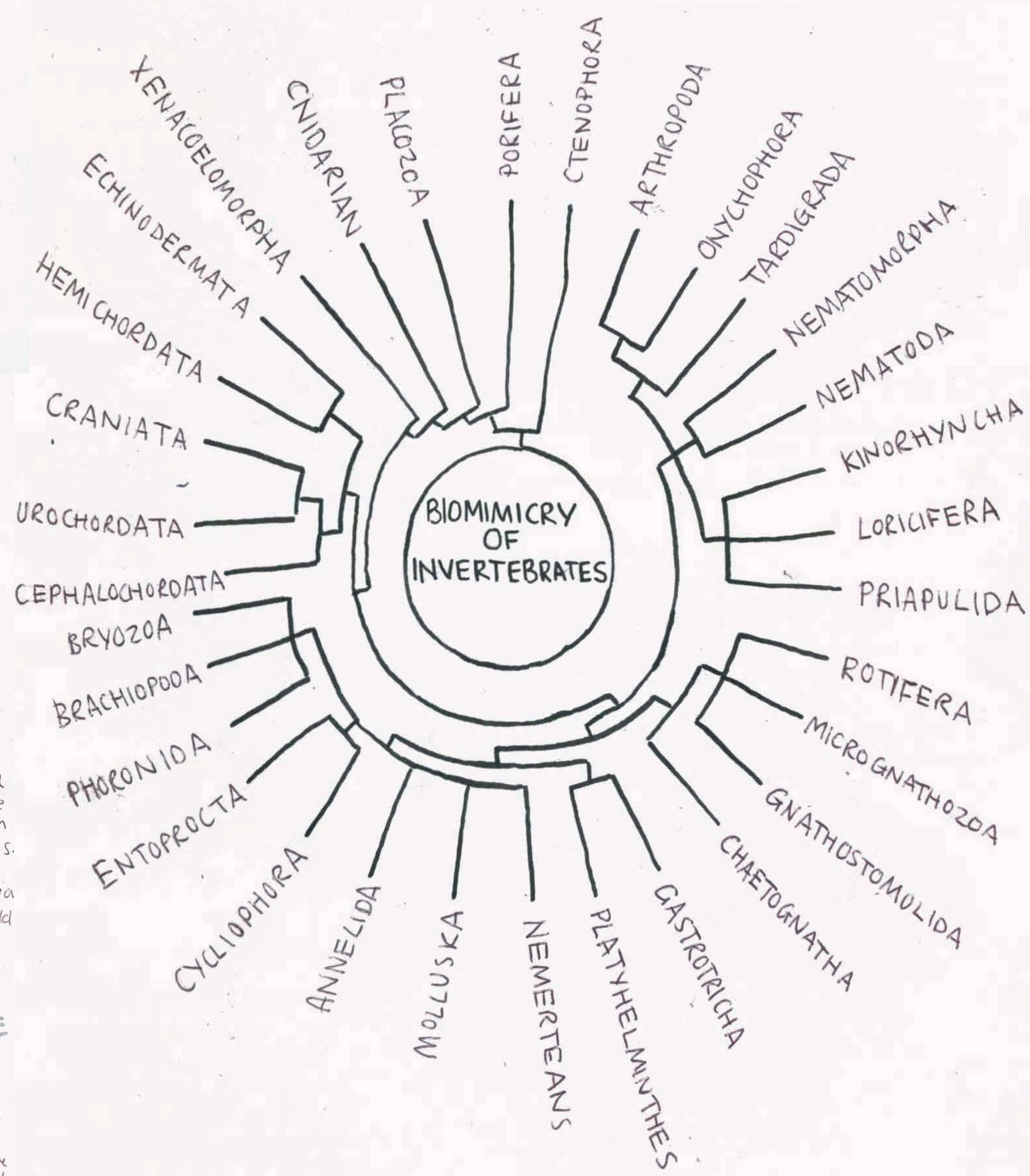

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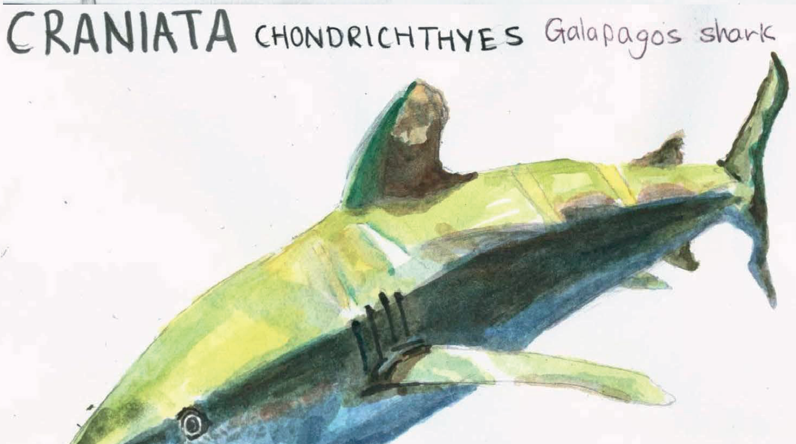

ANTI-BACTERIAL SKIN
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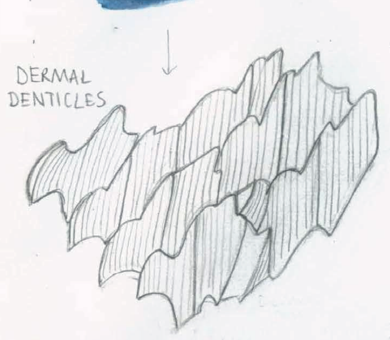

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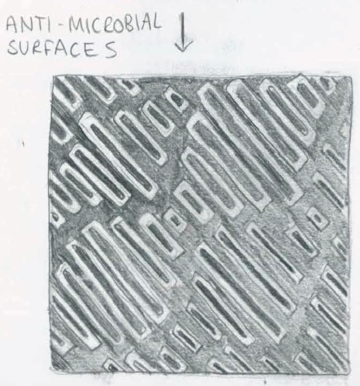

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LIGHTWEIGHT MATERIALS
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MOLLUSK BIVALVIA mussels

ADHESION Mussels adhere to both wet & dry surfaces by secreting strong, wear-resistant & elastic byssal threads made up of bundles of collagen surrounded by a thin cuticle.

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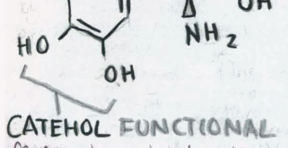

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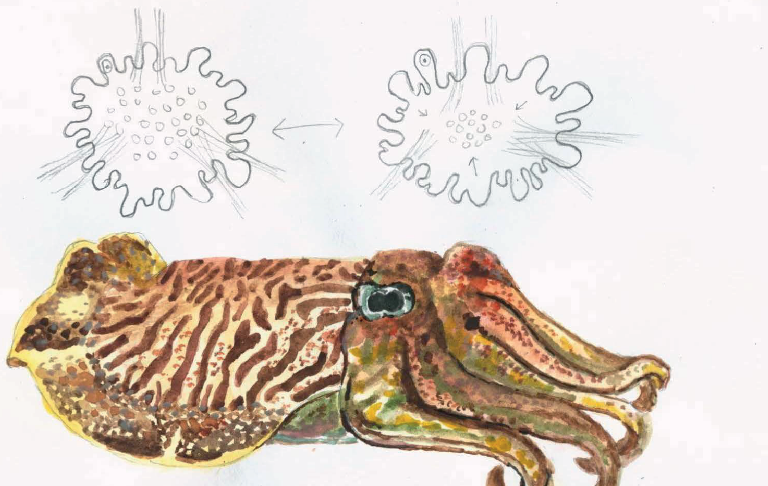
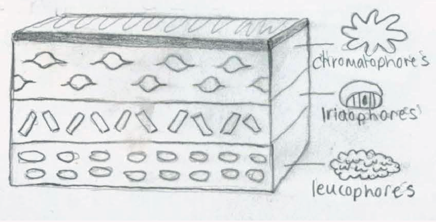


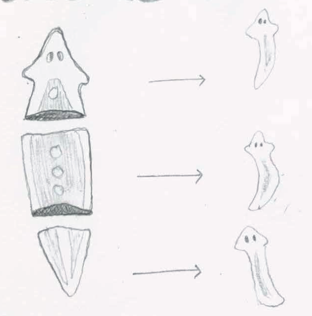
CAMOUFLAGE
Cuttlefish have chromatophores (pigment cells) in thier skin which can be made visible or invisible using muscles under direct control from neurons from the brain. They also have leucophores & iridophores, pigment cells under the chromatophores which help reflect light. Iridophores use a stack of platelets containing the protein reflectin to produce irridescent reflections whilst leucophores on the bottom reflect almost all incident light. They can also change the texture of thier skin using muscle bundles called papillae.



COLOUR & LIGHT
Aside from the use of this mechanism for camouflage, it could inspire the development of energy efficient screens & revolutionize how we colour the world around us.

PLATYHELMINTHES Flatworms

TISSUE REGENERATION

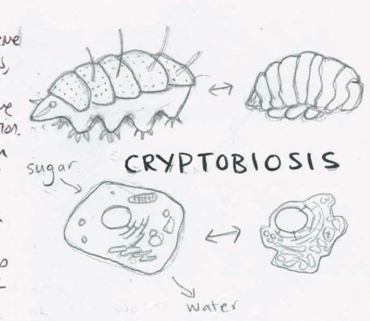


Platyhelminthes such as Dugesia have the remarkable ability to regenerate full bodies from cut up segments. Severing body parts sets off a cascade of stem cell signals which activate the creation of the body part that has been lost. Some flatworms even use this as a method of asexual reproduction.

MEDICINE
Researchers analysing the composition of stem cells & proteins in flatworms have discovered a protein critical for the maintainance of pluripotent adult stem cells in both humans & platyhelminthes. Translating our understanding of regeneration in flatworms could guide the development of regenerative medicine in humans.

TARDIGRADA Water bear / Moss piglet

RESISTANCE
Tardigrades can survive in very extreme conditions. They are resistant to X-rays, can survive in vacuums, high pressures, high temperatures, extreme cold & can survive extreme desication. To do this they use a mechanism of cryptobiosis in which they enter an ametabolic state, expel 99% of thier water & replace it with a sugar which acts as an anti-freeze. The tardigrade then rolls up into a tun & is covered in a layer of wax until normal conditions return.

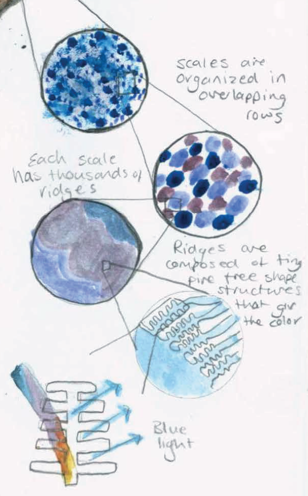


PRESERVATION
Understanding cryptobiosis & its preservation mechanism could open up new possibilities in food preservation & the transport & preservation of organs & other tissue for medical use.

ARTHROPODA LEPIDOPTERA Morpho Butterfly

COLOUR EFFECTS

Butterfly wings consist of multi-layered ribbed structures, covered by scales. The colours perceived on the wings are a function of the shape, size & arrangement of the scales. The butterfly wing consists of several strata & pigment & structural scales. Which overlap for example, the iridescent blue of Morpho butterflies is produced by structural bottom scales & transparent cover scales.



COLOUR & WINDOWS

By mimicing the colour effects of butterflies we could develope materials of any colour without using any pigment, dyes, water or treatment. Furthermore, this could be used to produce spectrally selective glass which could reduce the need for low emmisivity coatings on windows which are usually applied as a seperate material.

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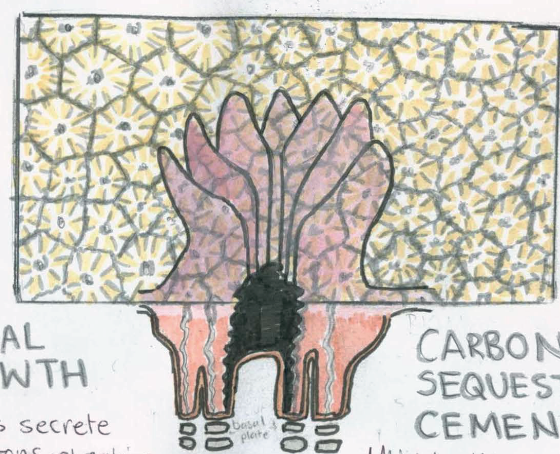

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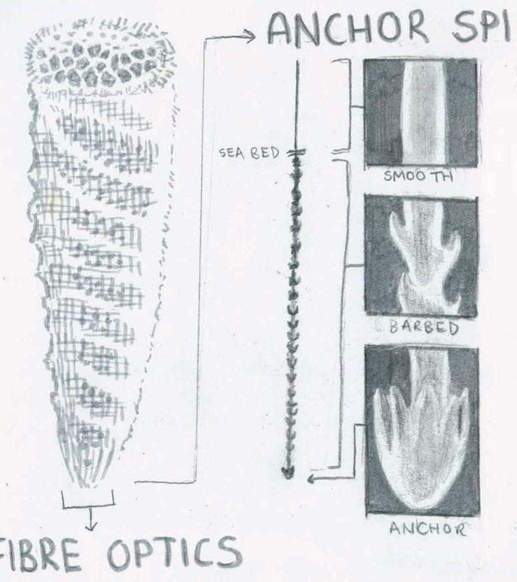

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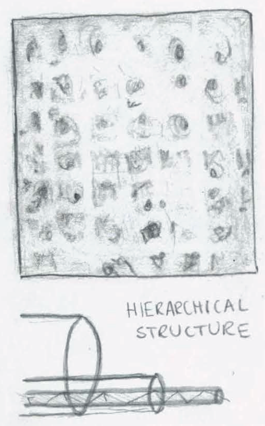

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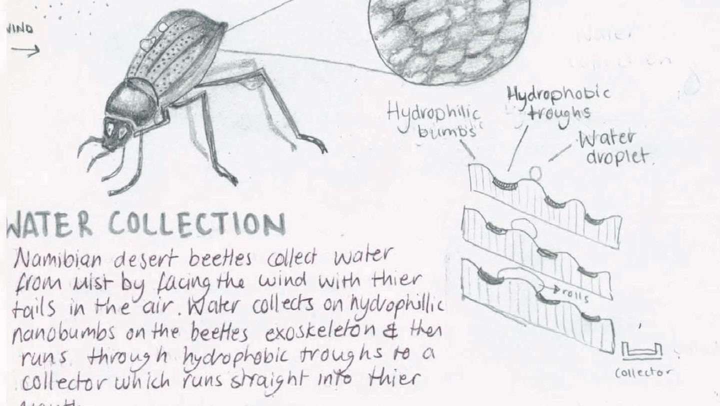

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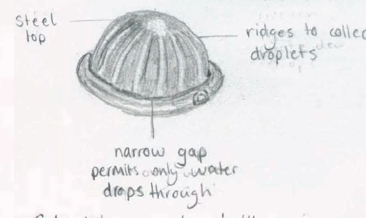

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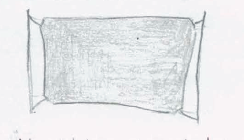

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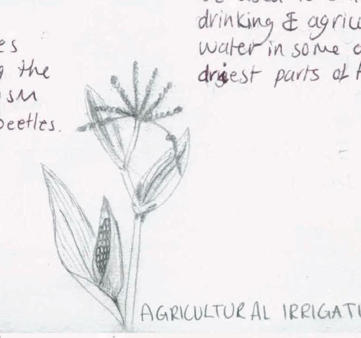

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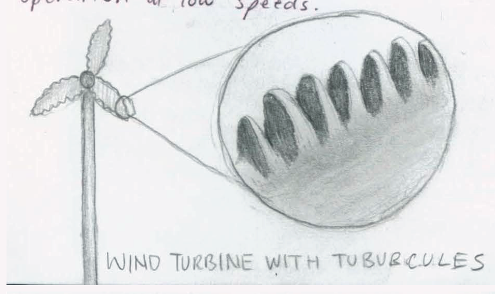

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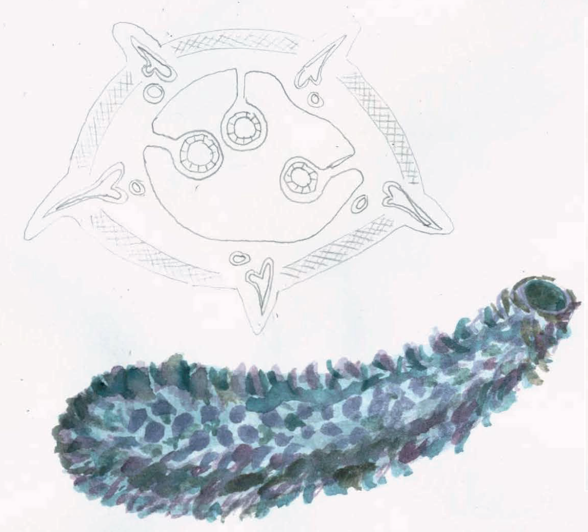

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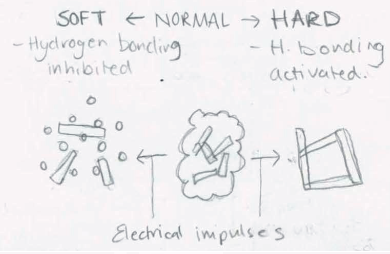

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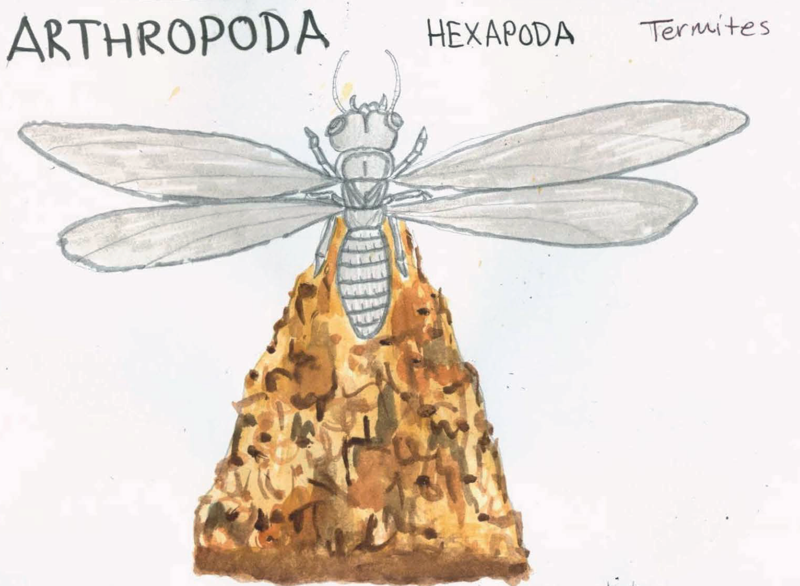

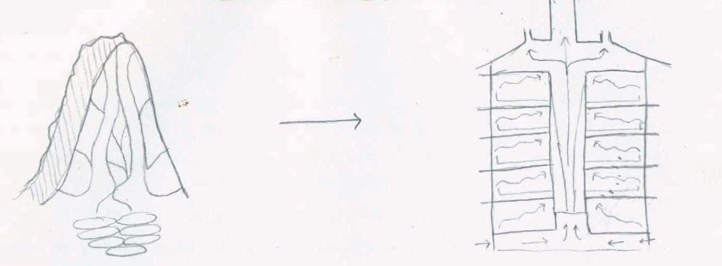

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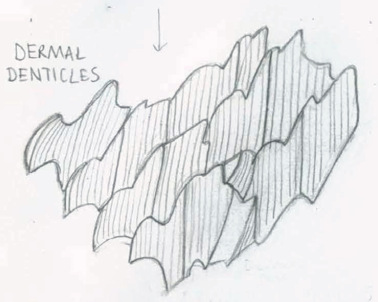

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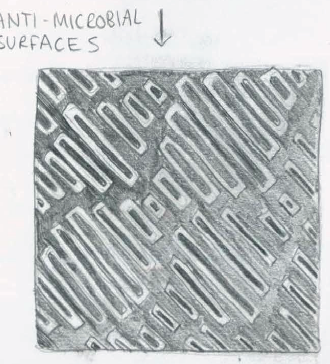

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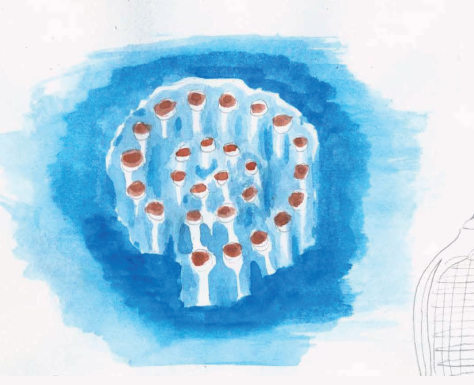

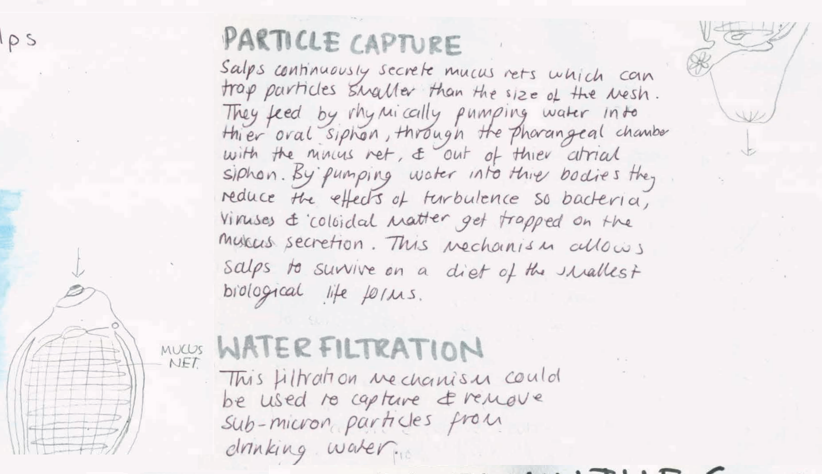

PARTICLE CAPTURE

Salps continuously secrete mucus nets which can trap particles smaller than the size of the mesh. They feed by rhymically pumping water into thier oral siphon, through the pharangeal chamber with the mucus net, & out of thier atrial siphon. By pumping water into thier bodies they reduce the effects of turbulence so bacteria, viruses & coloidal matter get trapped on the mucus secretion. This mechanism allows salps to survive on a diet of the smallest biological life forms.

WATER FILTRATION

This filtration mechanism could be used to capture & remove sub-micron particles from drinking water.

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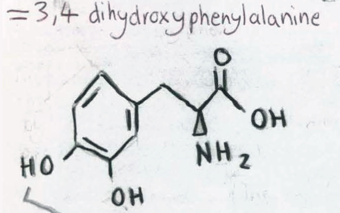

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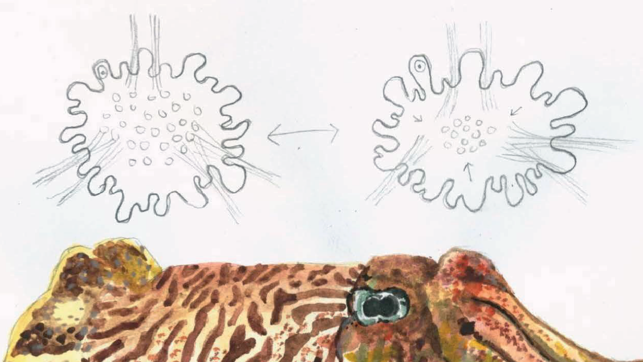

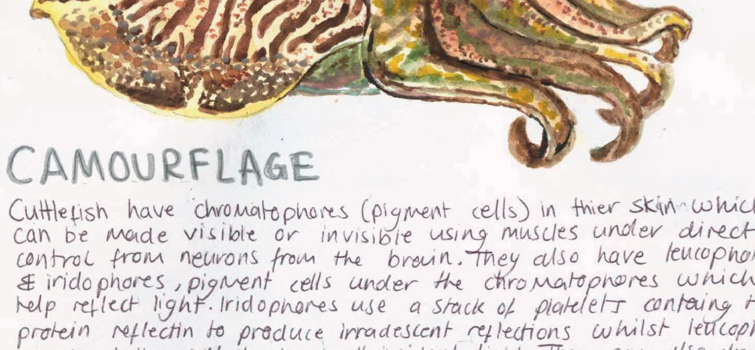

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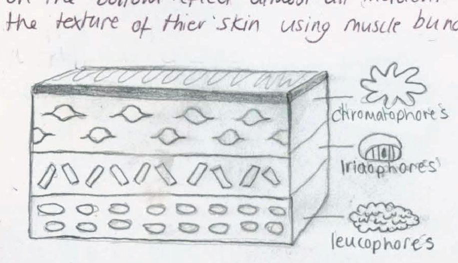
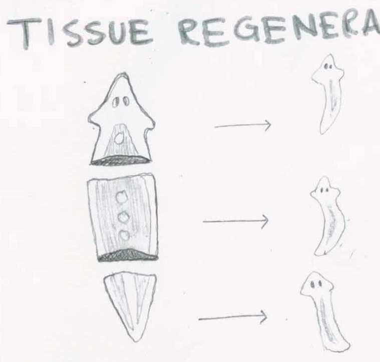


COLOUR & LIGHT

Aside from the use of this mechanism for camouflage it could inspire the development of energy efficient screens & revolutionize how we colour the world around us.

PLATYHELMINTHES Flatworms

TISSUE REGENERATION



Platyhelminthes such as Dugesia have the remarkable ability to regenerate full bodies from cut up segments. Severing body parts sets off a cascade of stem cell signals which activate the creation of the body part that has been lost. Some flatworms even use this as a method of asexual reproduction.

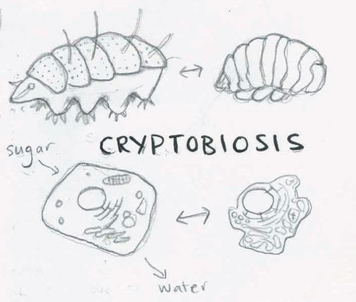
MEDICINE

Researchers analysing the composition of stem cells & proteins in flatworms have discovered a protein critical for the maintainance of pluripotent adult stem cells in both humans & platyhelminthes. Translating our understanding of regeneration in flatworms could guide the development of regenerative medicine in humans.

TARDIGRADA Water bear / Moss piglet

RESISTANCE

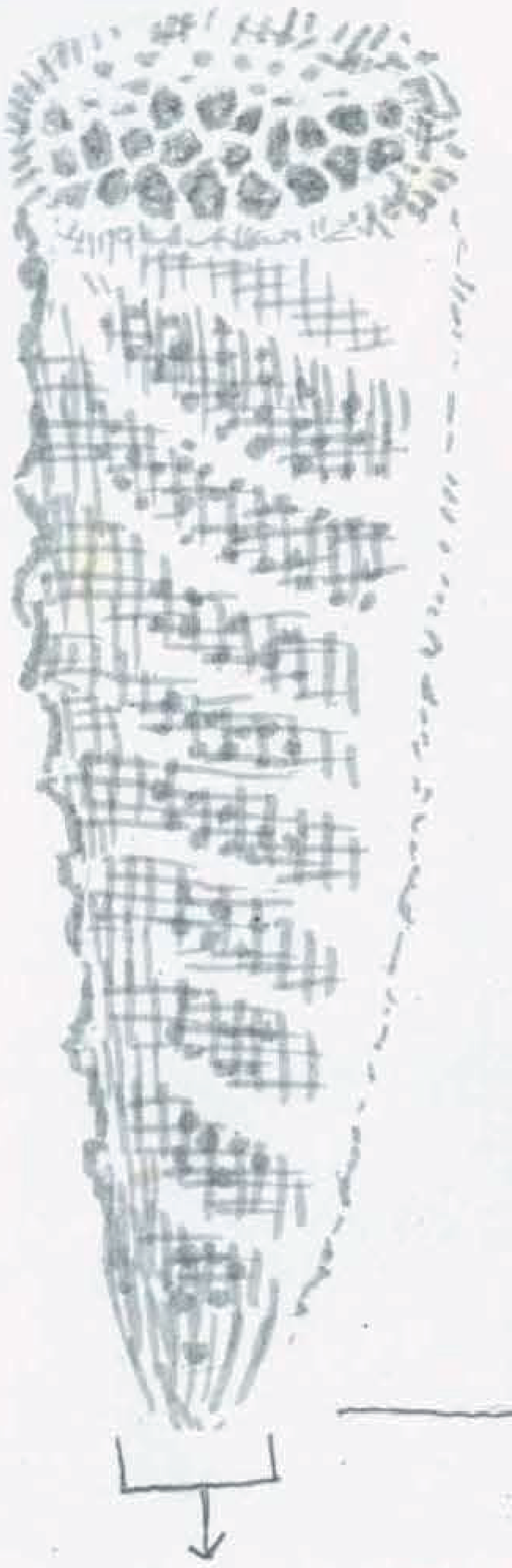
Tardigrades can survive in very extreme conditions. They are resistant to X-rays, can survive in vacuums, high pressures, high temperatures, extreme cold & can survive extreme dessication. To do this they use a mechanism of cryptobiosis in which they enter an ametabolic state, expel 99% of thier water & replace it with a sugar which acts as an anti-freeze. The tardigrade then rolls up into a tun & is covered in a layer of wax until normal conditions return.



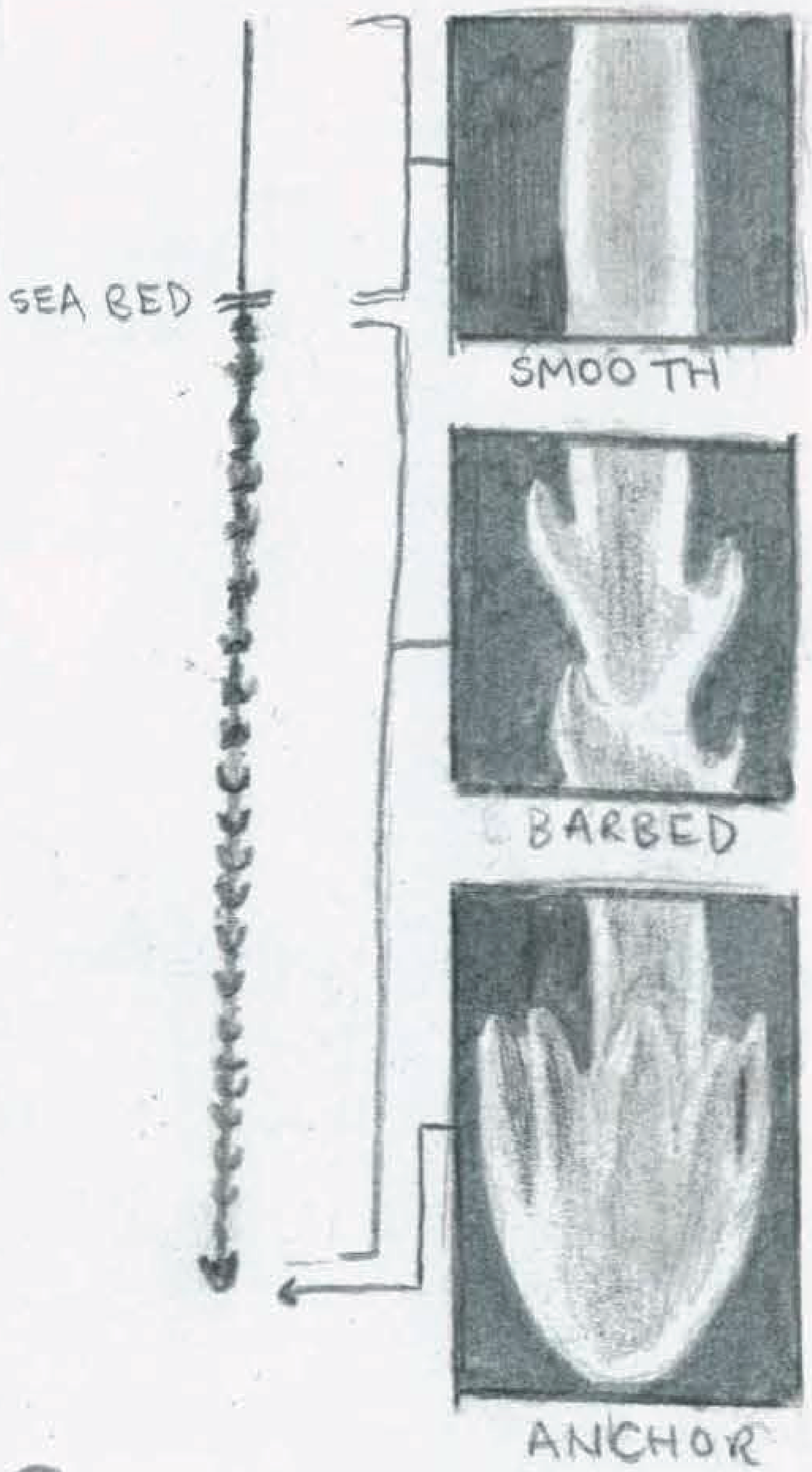
PRESERVATION

Understanding cryptobiosis & its preservation mechanism could open up new possibilities in food preservation & the transport & preservation of organs & other tissue for medical use

PORIFERA HEXACTINELLIDA Glass sponge

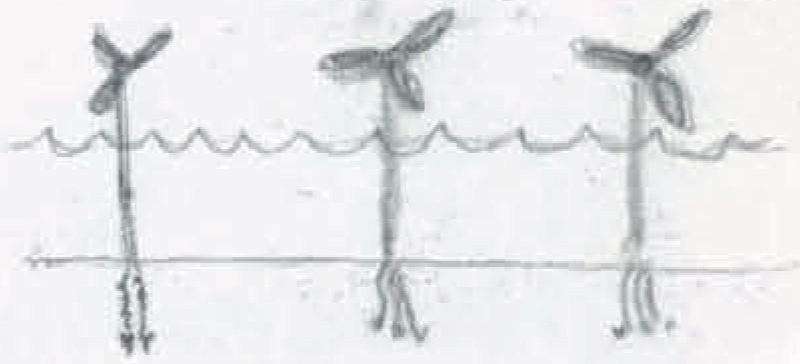


ANCHOR SPICULES



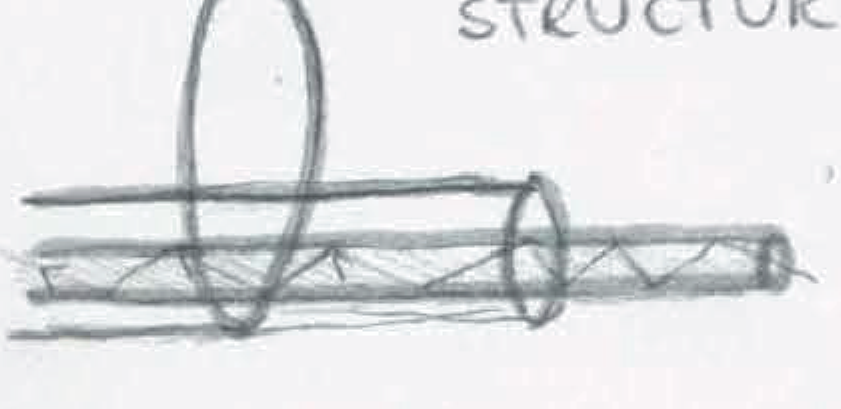
Around 200 spicules anchor each glass sponge to the sea floor. The below ground morphology forms a strong hold-fast but also allows for considerable pliancy rather than rigidity. This allows for a much more efficient anchoring system in terms of materials. Potential:

ANCHORING OFF-SHORE WIND TURBINES



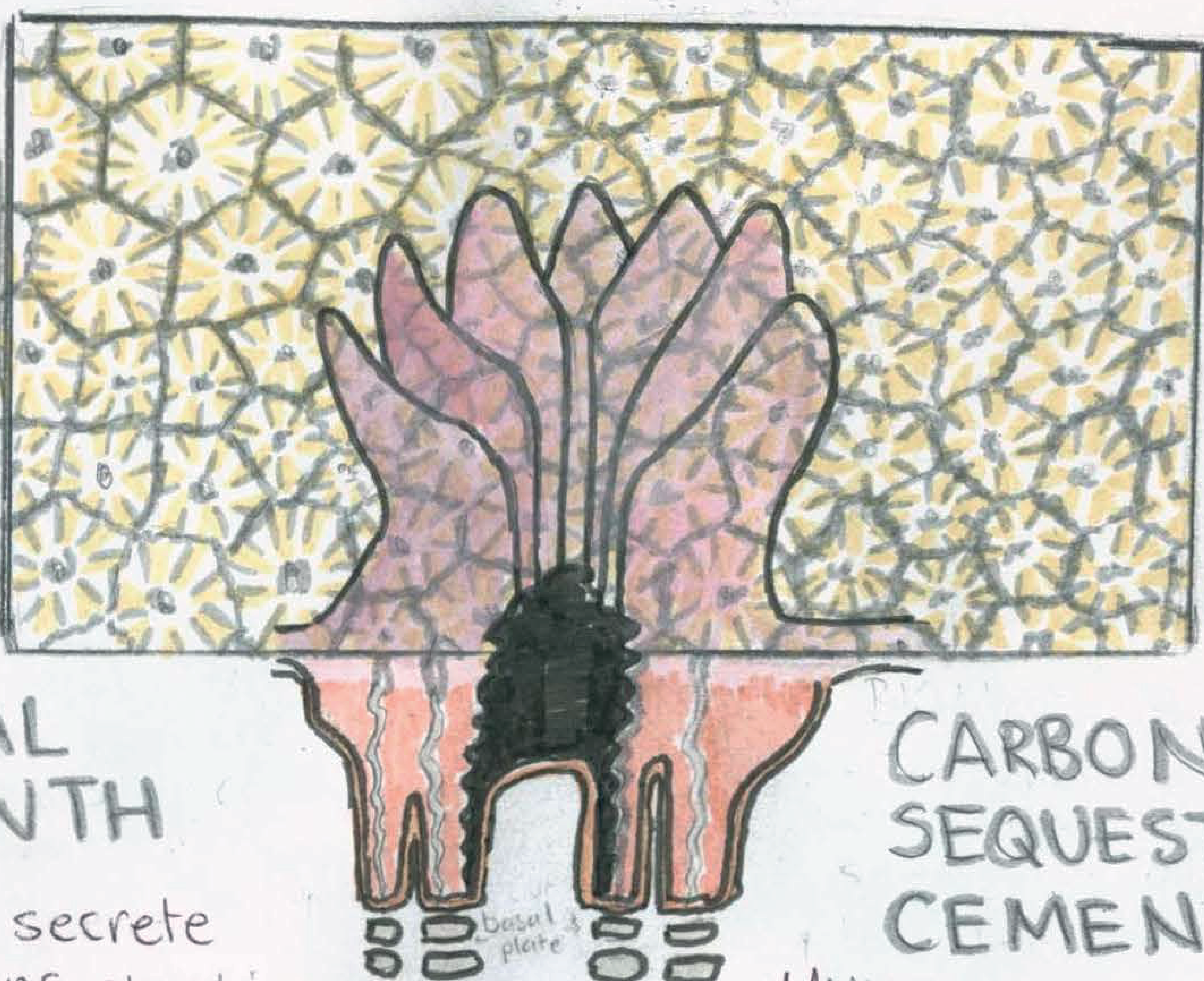
FIBRE OPTICS

HIERARCHICAL STRUCTURE



The silicon dioxide fibers of the glass sponge transmit light better than fibre optics and are made from benign materials at ambient temperature. Manufacture of fibre-optic cables, in contrast, occurs at high temperatures where the addition of specialized impurities, such as sodium which improves light conduction, is difficult. Glass sponges could help us design flexible (rather than brittle), faster fibre optic cables using far less energy.

CNIDARIAN ANTHOZOA Stony corals



CORAL GROWTH

Polyps secrete skeletons of calcium carbonate ($CaCO_3$) in the form of a cup in which the polyp sits. Ocassionally the polyps lift up & create a new base above it, elevating the coral upward using carbon dioxide & calcium from the ocean.

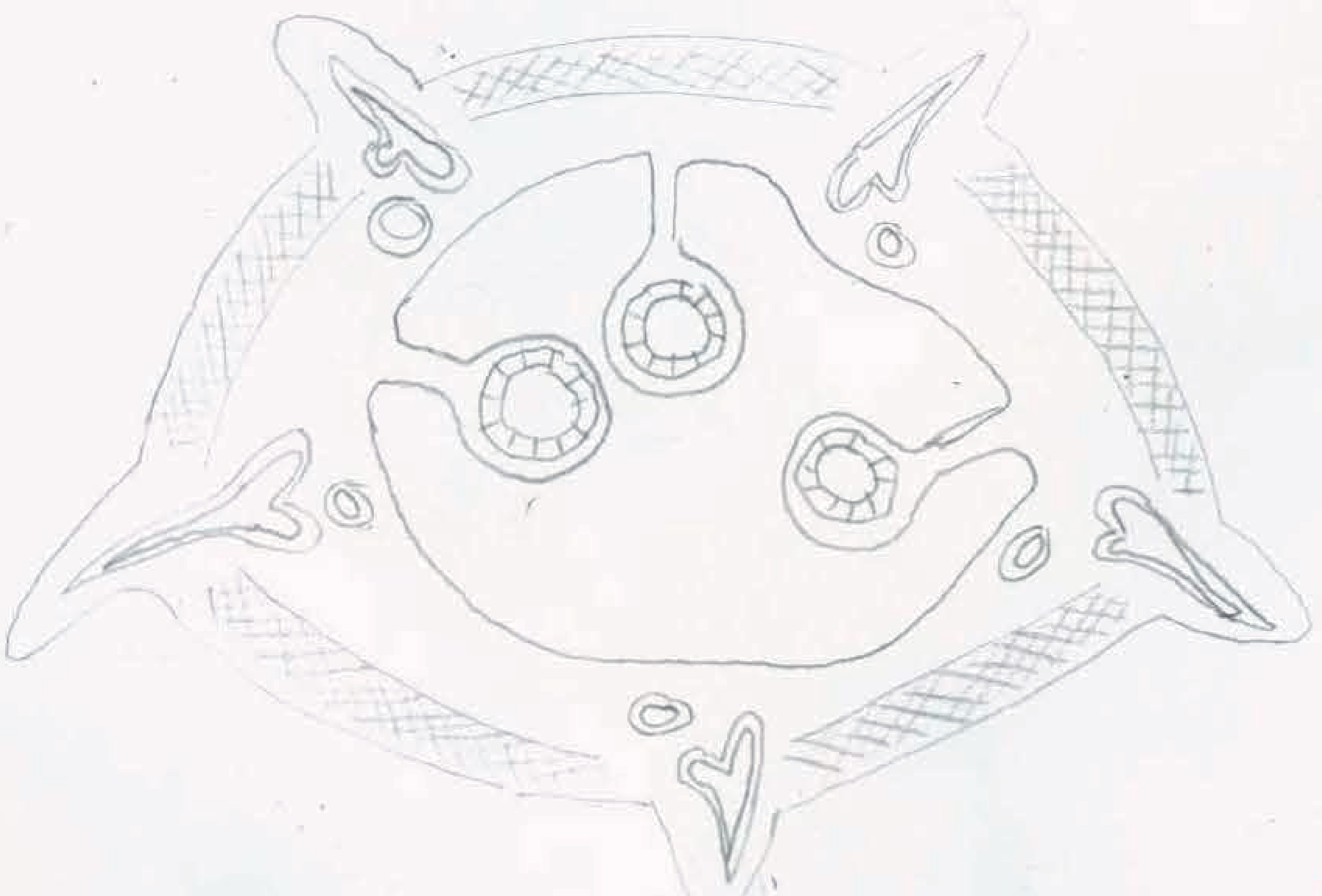
CARBON SEQUESTERING CEMENT

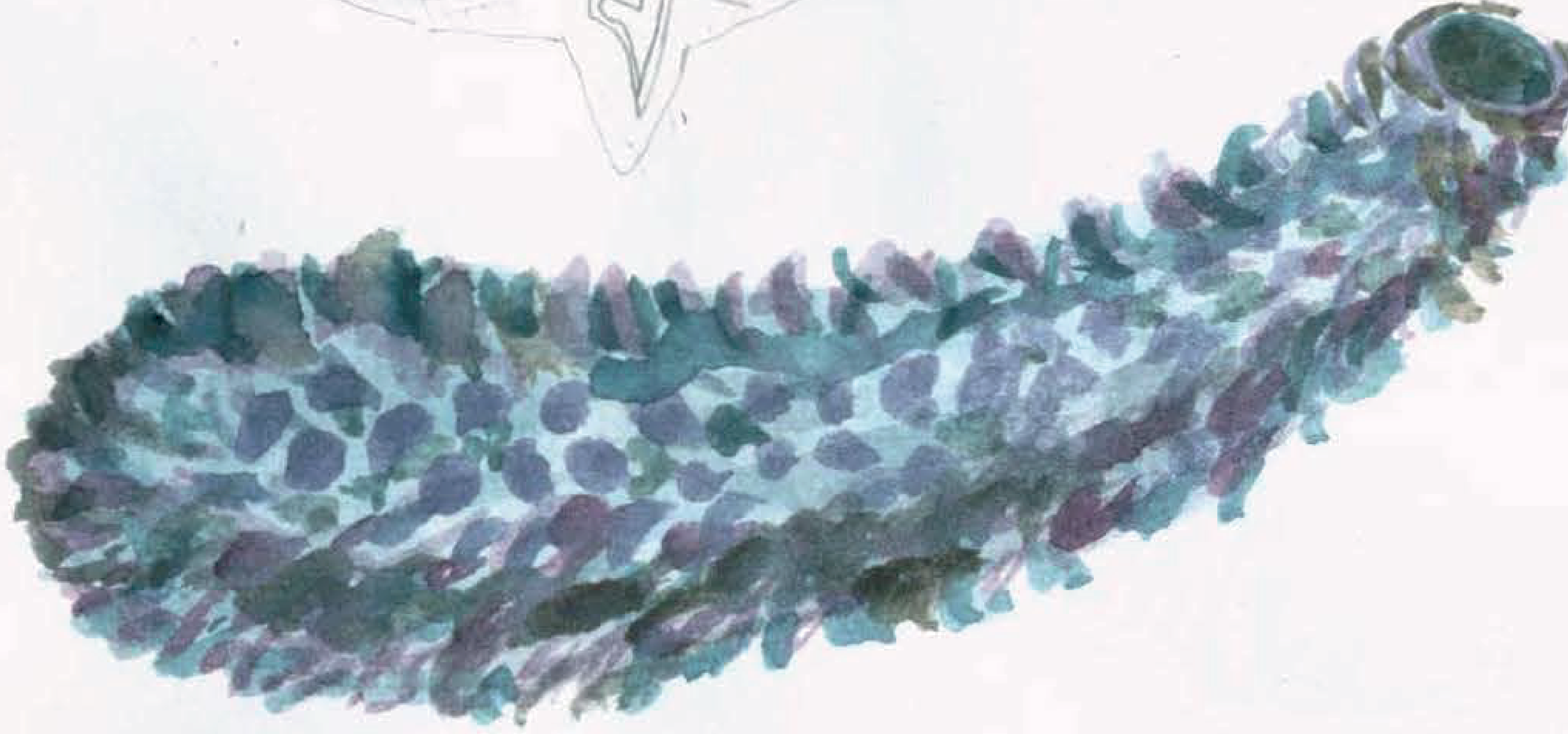
Mimicing the mechanism by which corals build thier skeletons could transform th cement industry, which is currently responsible for 8% of total CO_2 emmissions. The cement company Calcera now makes cement by dissolving waste CO_2 from power plants in seawater to form carbonate ions (CO_3^{2-}) which mix with calcium in the ocean to form a solid cement alternative whilst sequestering CO_2.

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow CO_3^{2-} + 2H^+$$

$$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3$$

ECHINODERMATA HOLOTHUROIDEA Sea cucumber





RIGIDITY & FLEXIBILITY

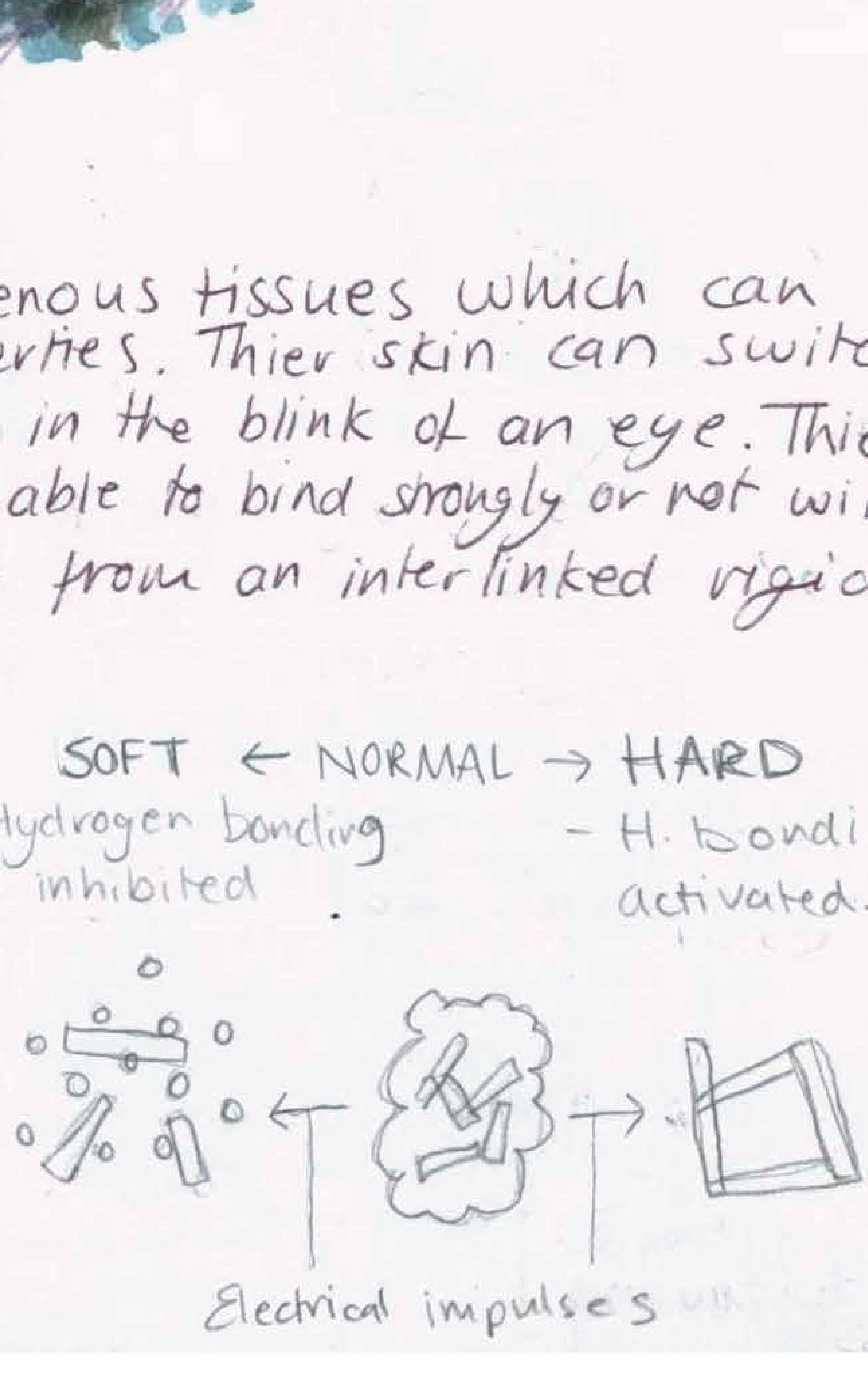
Sea cucumbers have mutable collagenous tissues which can extensively change thier mechanical properties. Thier skin can switch between soft, normal & rigid states in the blink of an eye. Thier skin contains collagen fibrils which are able to bind strongly or not with other substances around them, switching from an interlinked rigid state to a loose flexible state.

SMART POLYMER

Researchers studying sea cucumber skin have developed a polymer which is flexible in aquous solvent & becomes rigid when the solvent evaporates. They hope to use this for 'selfing' medical devices & responsive brain implants

SOFT ← NORMAL → HARD

- Hydrogen bonding inhibited
- H. bonding activated.

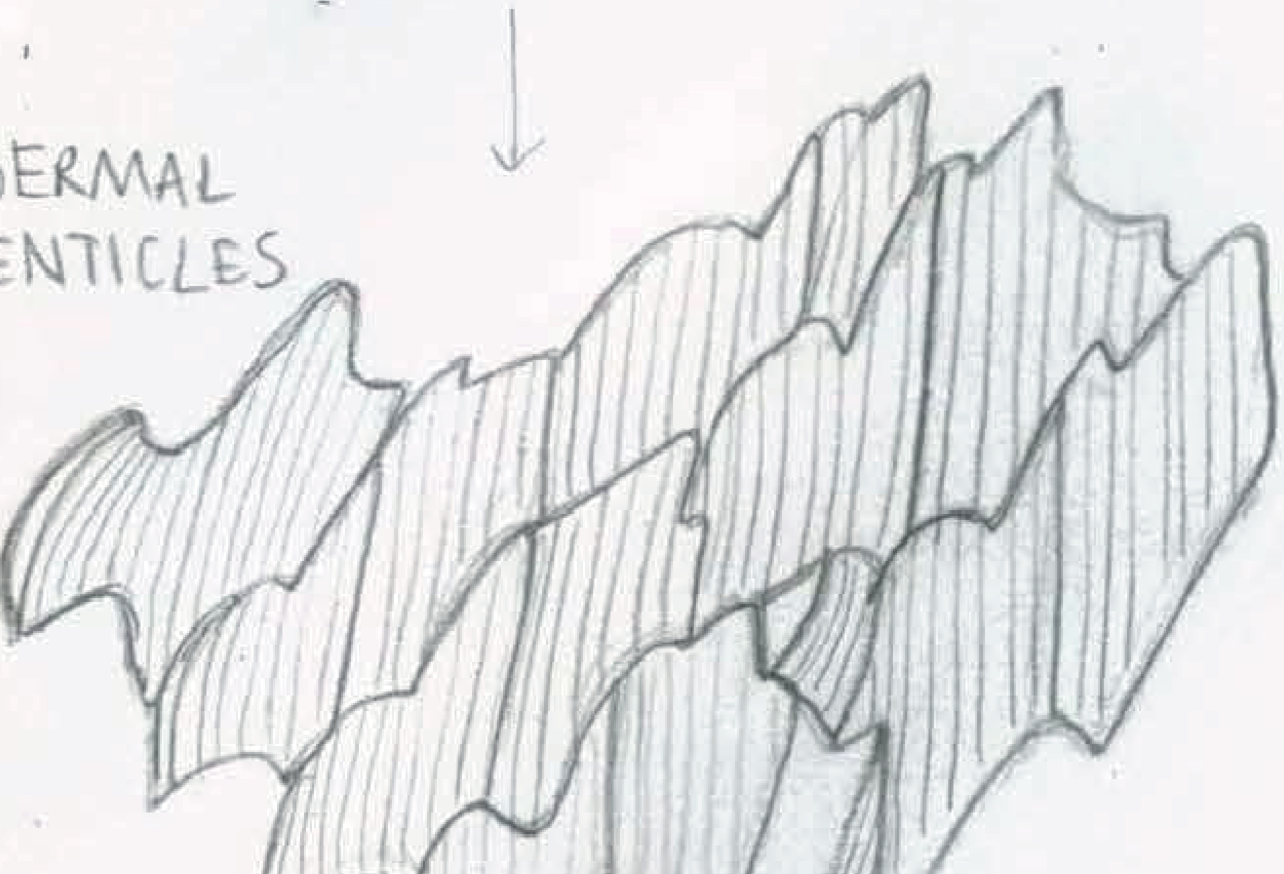


CRANIATA CHONDRICHTHYES Galapagos shark

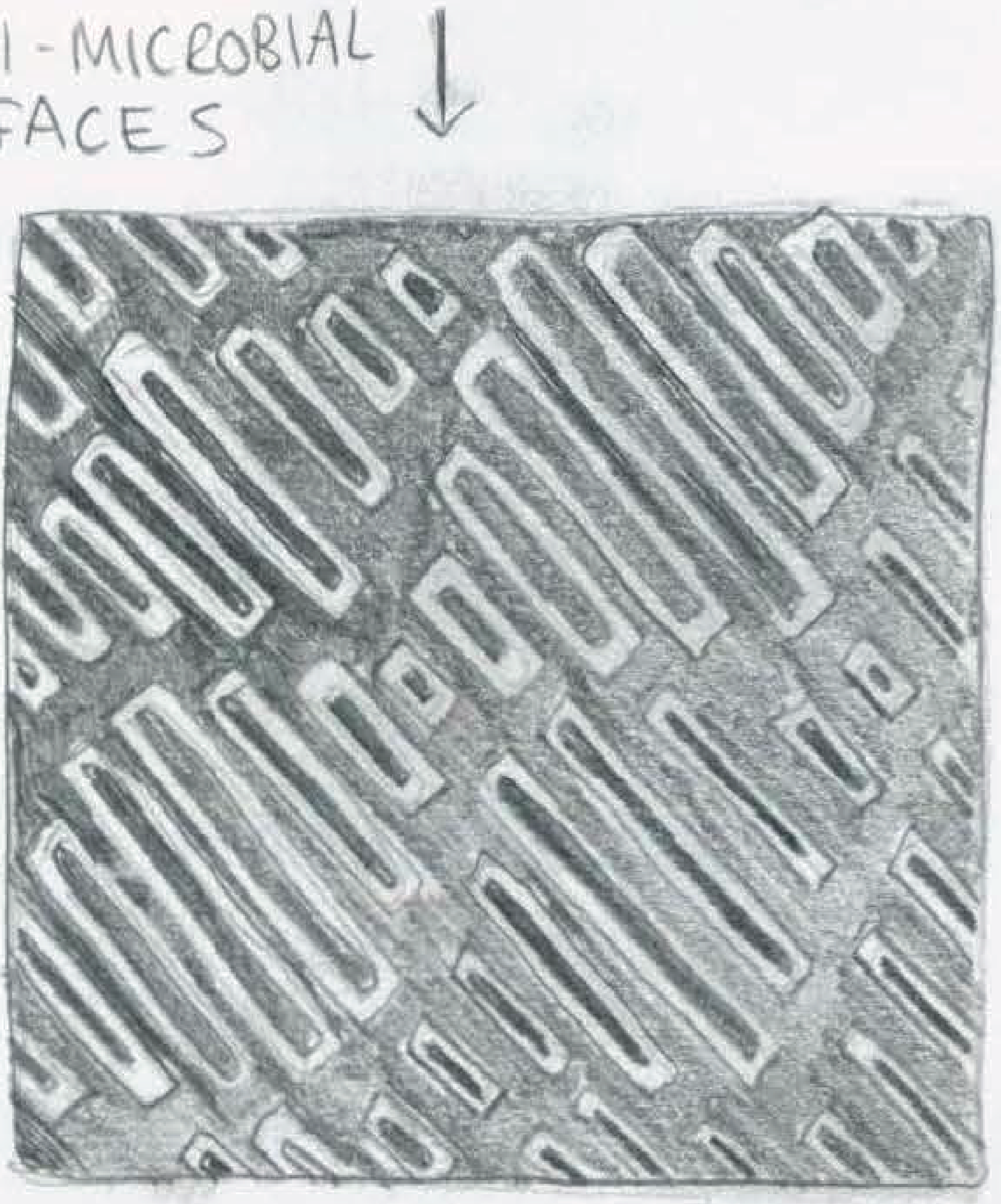
ANTI-BACTERIAL SKIN

The skin of a shark is covered in tiny scales called dermal dentticles which are arranged parralell to water flow. These dermal denticles are covered in microscopic bumbs & hollows. The topography makes the surface inhospitable to bacteria & other organisms as it would require too high an energy demand to reside upon.

DERMAL DENTICLES



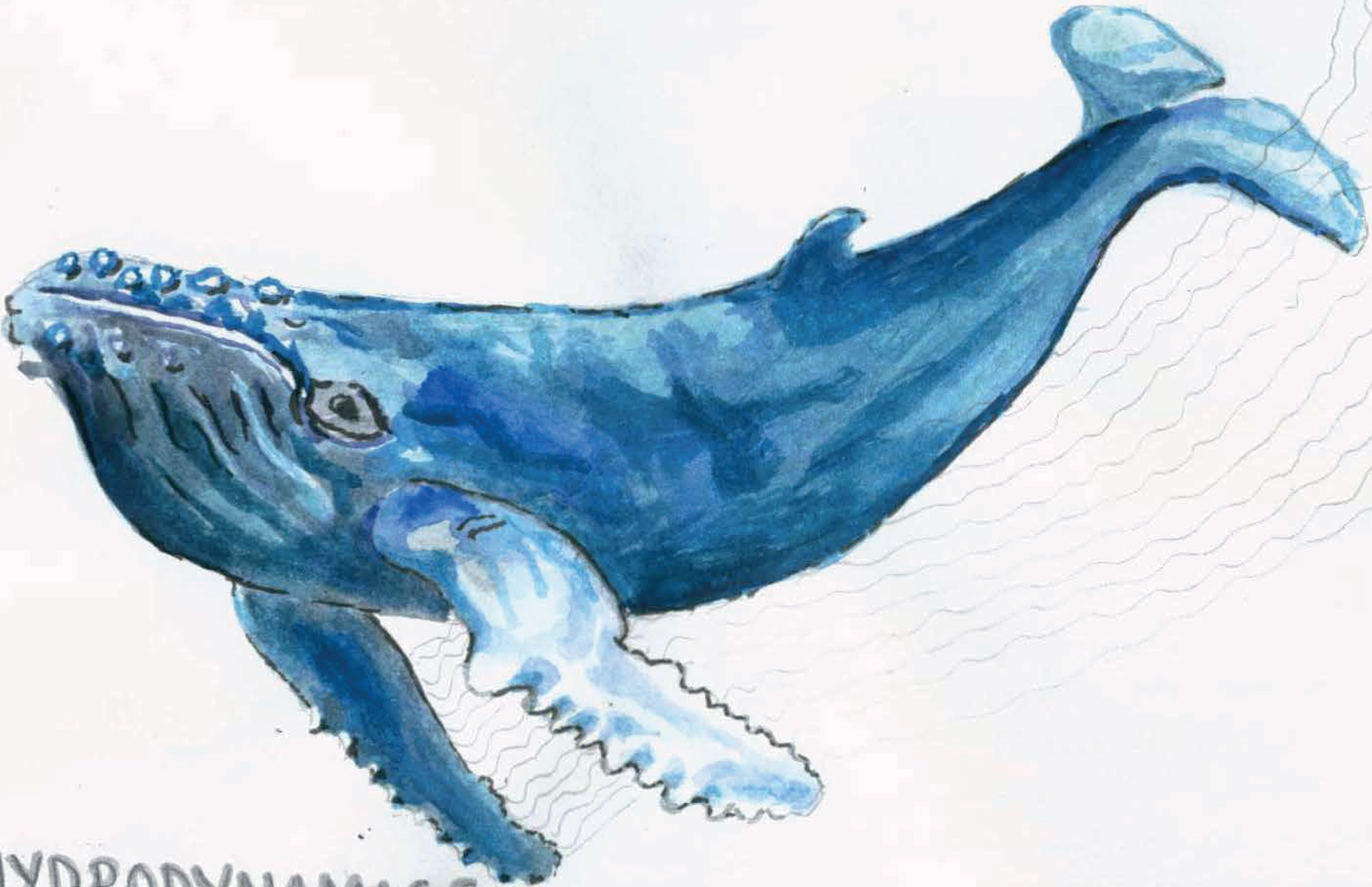
ANTI-MICROBIAL SURFACES



ANTI-BACTERIAL SURFACE

Inspired by the patterns of sharkskin you can produce a polymer topography which prevents bacteria developing on its surface. This reduces the need for anti-bacterial chemical agents & could be very useful in places like hospitals.

CRANIATA CETACEA Humpback whale

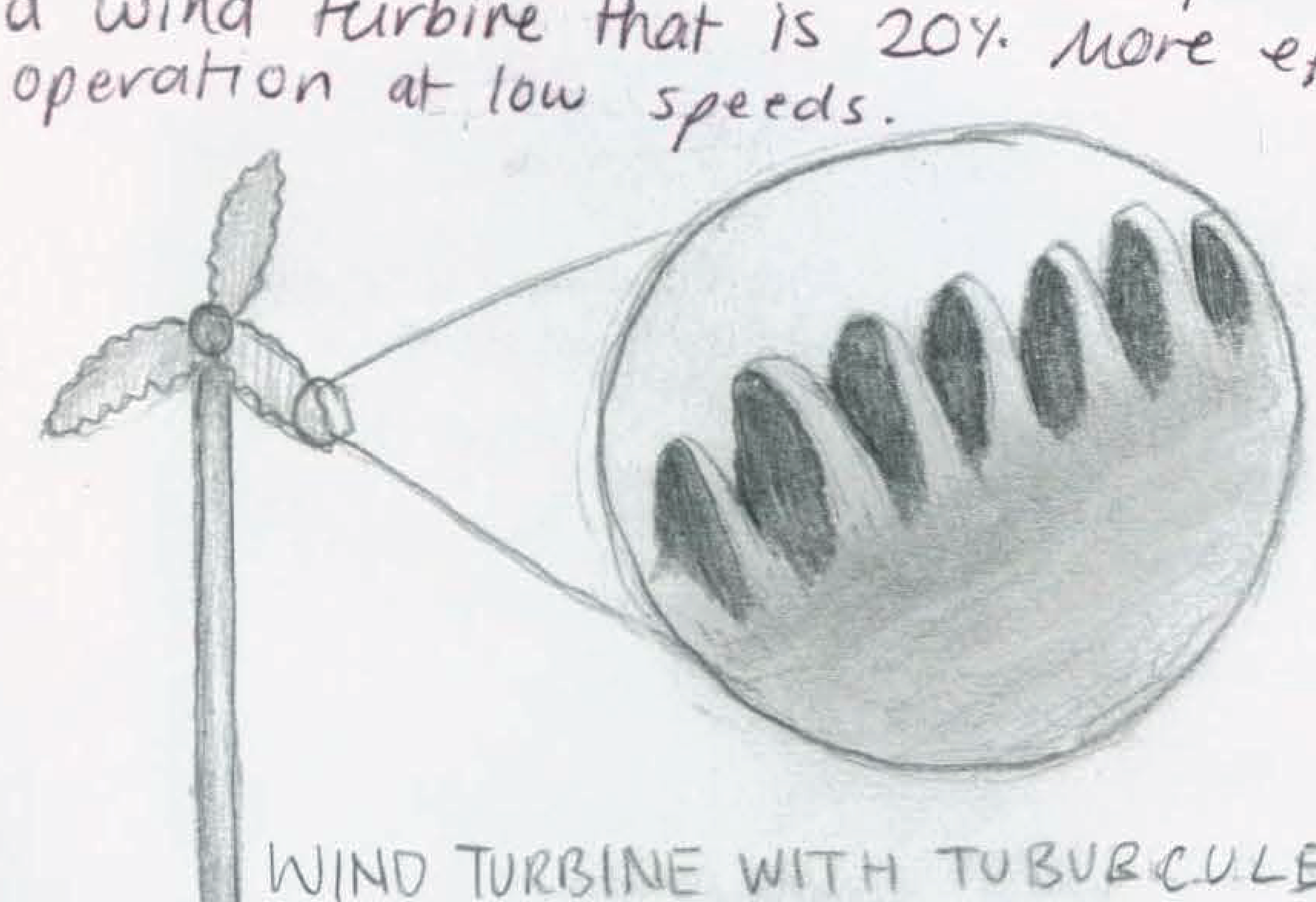


HYDRODYNAMICS

Humpback whales have long pectoral fins with uneven leading edges. The proturbulances of the fins, called tubercules induce vortices which create extra lift & allow the whale to maintain maneouverability at low speeds.

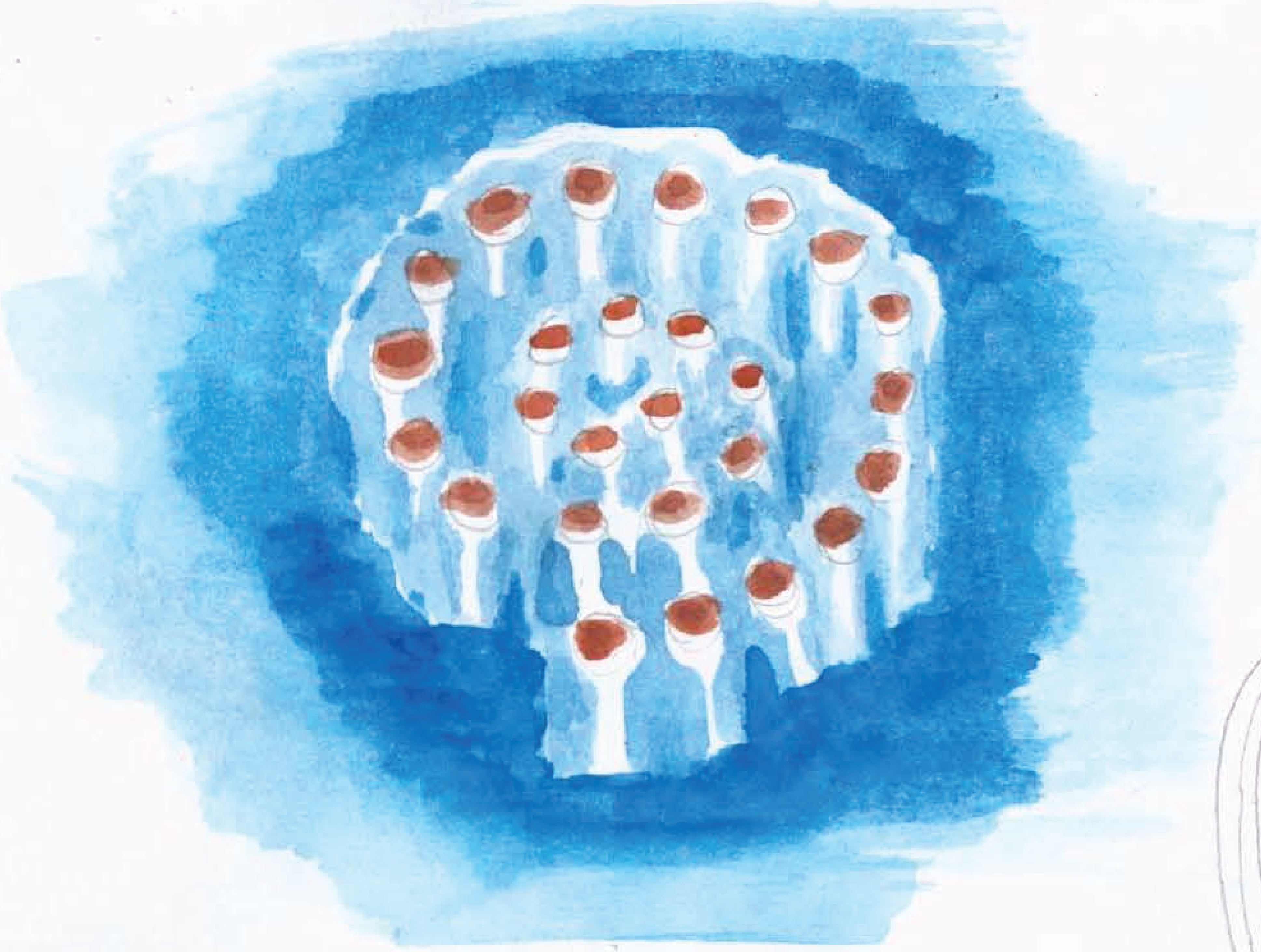
WIND TURBINES

A new windturbine blade incorpates tuburcules to produce a wind turbine that is 20% more efficient & maintains operation at low speeds.



WIND TURBINE WITH TUBURCULES

UROCHORDATA THALIACEA Salps



PARTICLE CAPTURE

Salps continuously secrete mucus nets which can trap particles smaller than the size of the mesh. They feed by rhymically pumping water into thier oral siphon, through the pharangeal chamber with the mucus net, & out of thier atrial siphon. By pumping water into thier bodies they reduce the effects of turbulence so bacteria, viruses & coloidal matter get trapped on the mucus secretion. This mechanism allows salps to survive on a diet of the smallest biological life forms.

WATER FILTRATION

This filtration mechanism could be used to capture & remove sub-micron particles from drinking water.

PLATYHELMINTHES Flatworms

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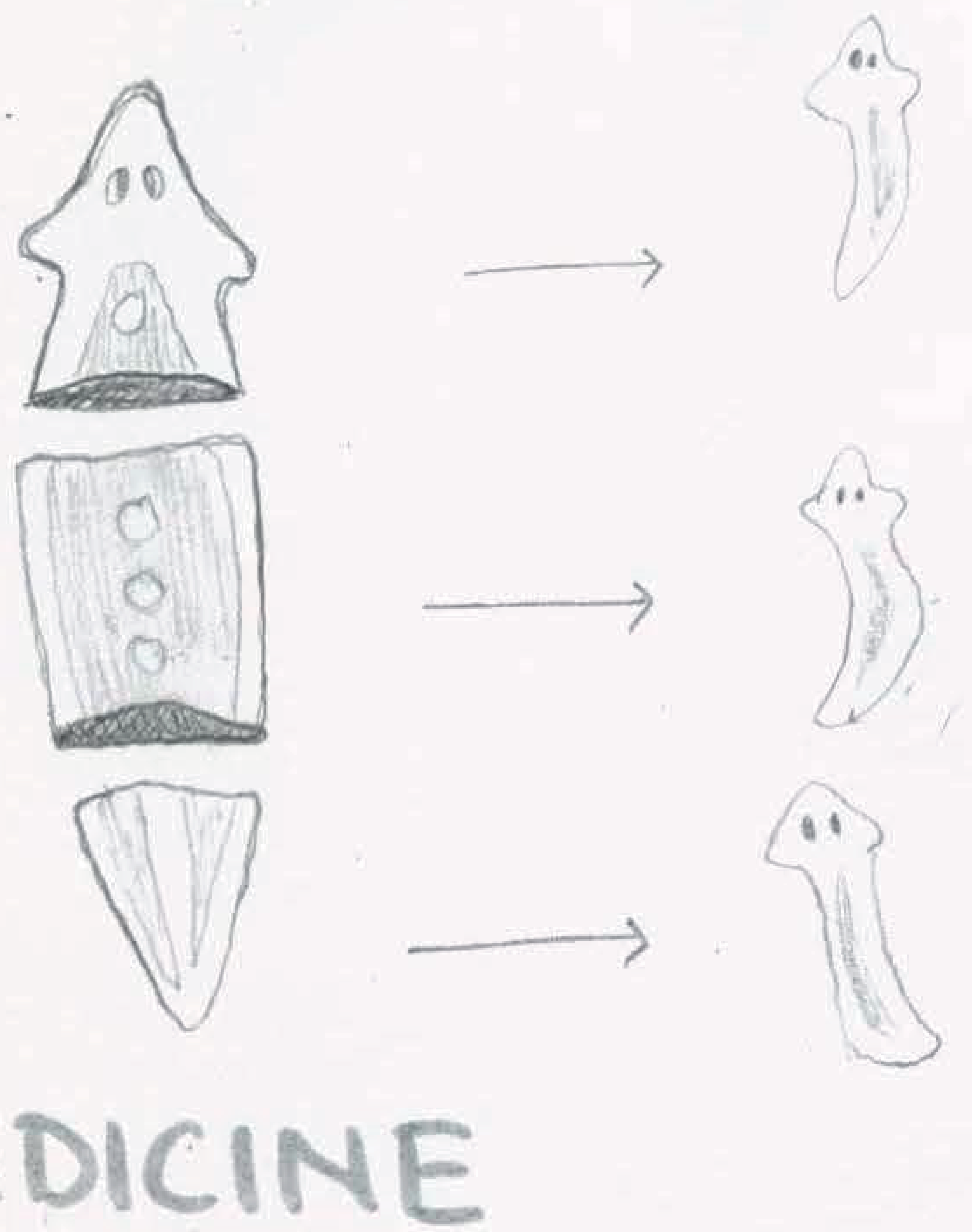

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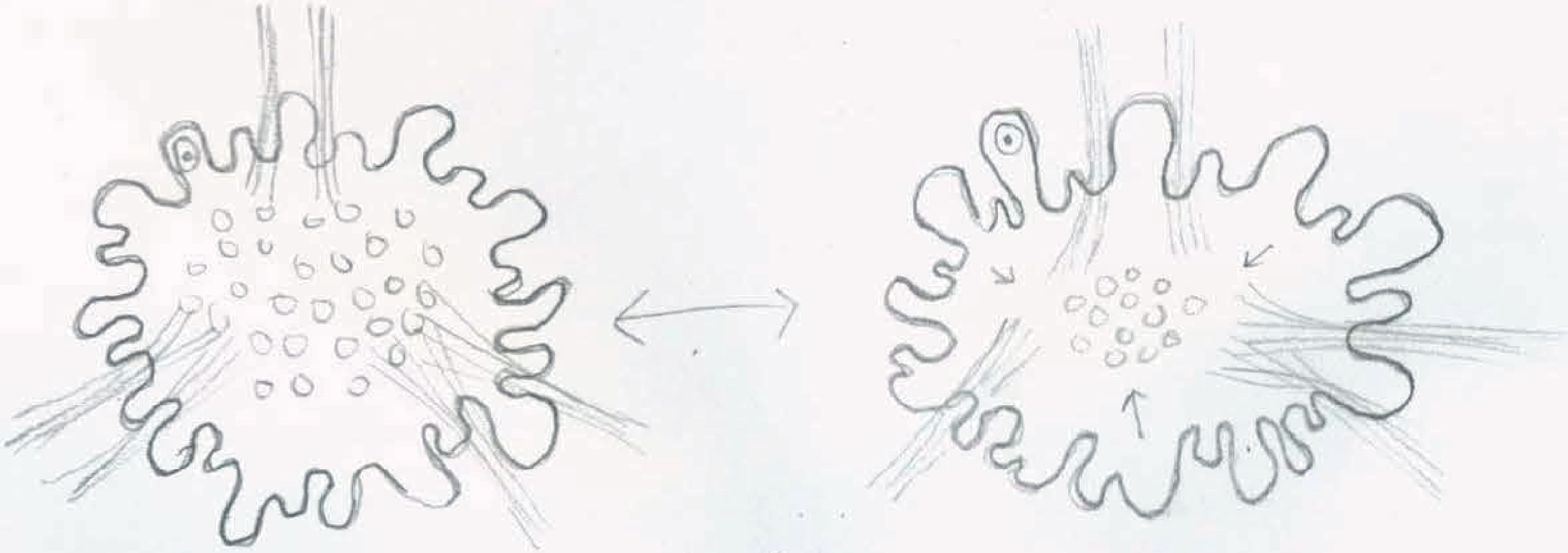
MOLLUSK CEPHALOPOD Cuttlefish



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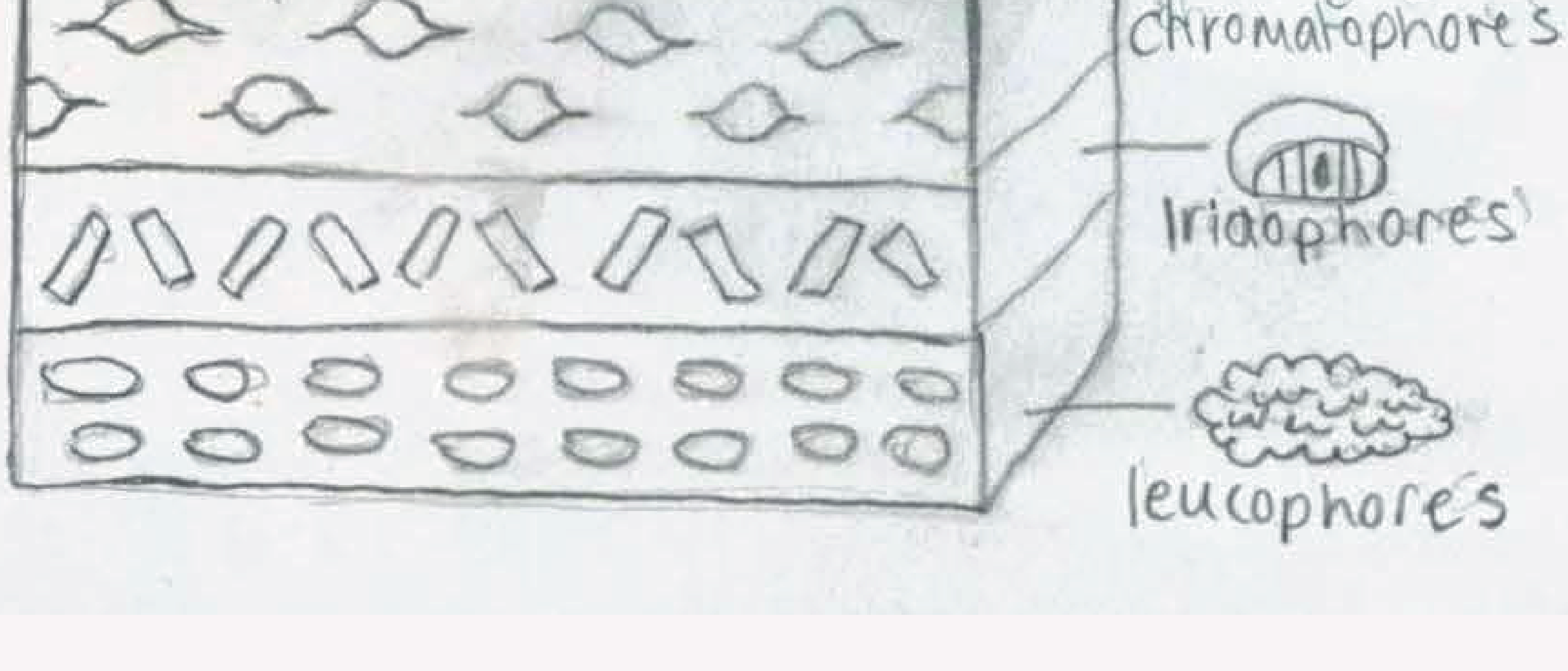

COLOUR & LIGHT

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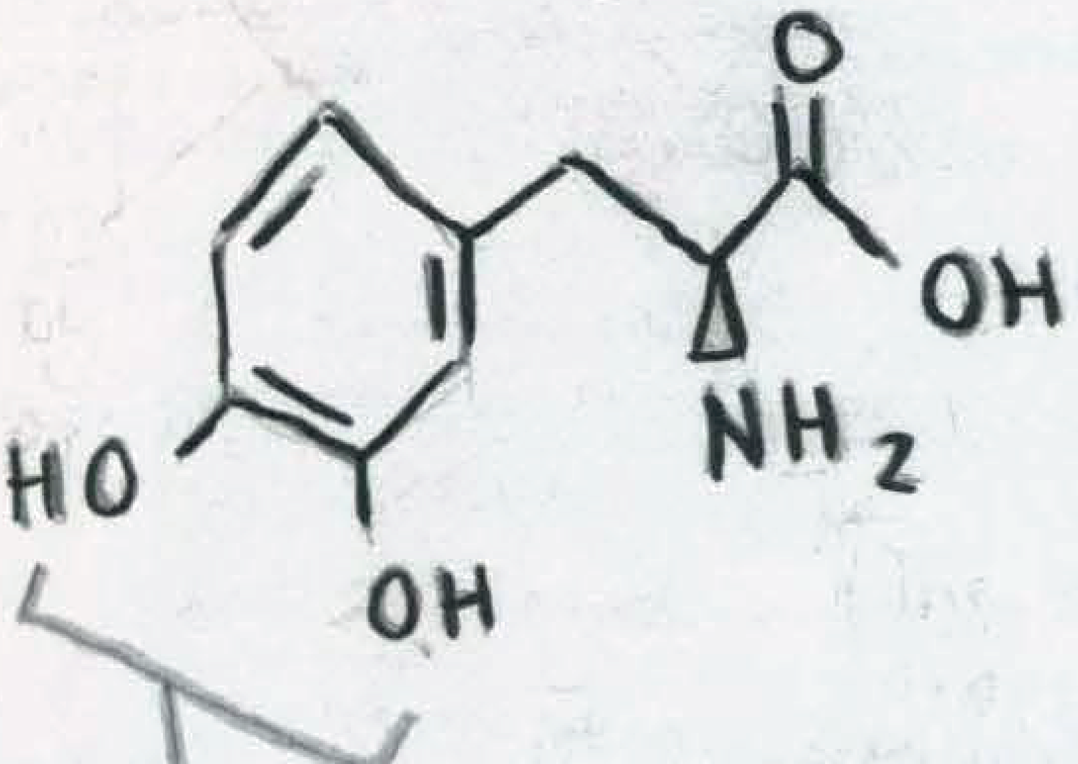
MOLLUSK BIVALVIA mussels

ADHESION Mussels adhere to both wet & dry surfaces by secreting strong, wear-resistant & elastic byssal threads made up of bundles of collagen surrounded by a thin cuticle.

ADHESIVE AMINO ACID

= 3,4 dihydroxyphenylalanine



CATEHOL FUNCTIONAL GROUP forms strong bonds with adjacent molecules & metal atoms on solid surface.

NON-TOXIC ADHESIVES

Mussel inspired adhesives can be made by modifying soya proteins so that the amino acids mimic those found in byssal threads. This produces a non-toxic, water resistant adhesive alternative to carcinogenic formaldehyde adhesives.

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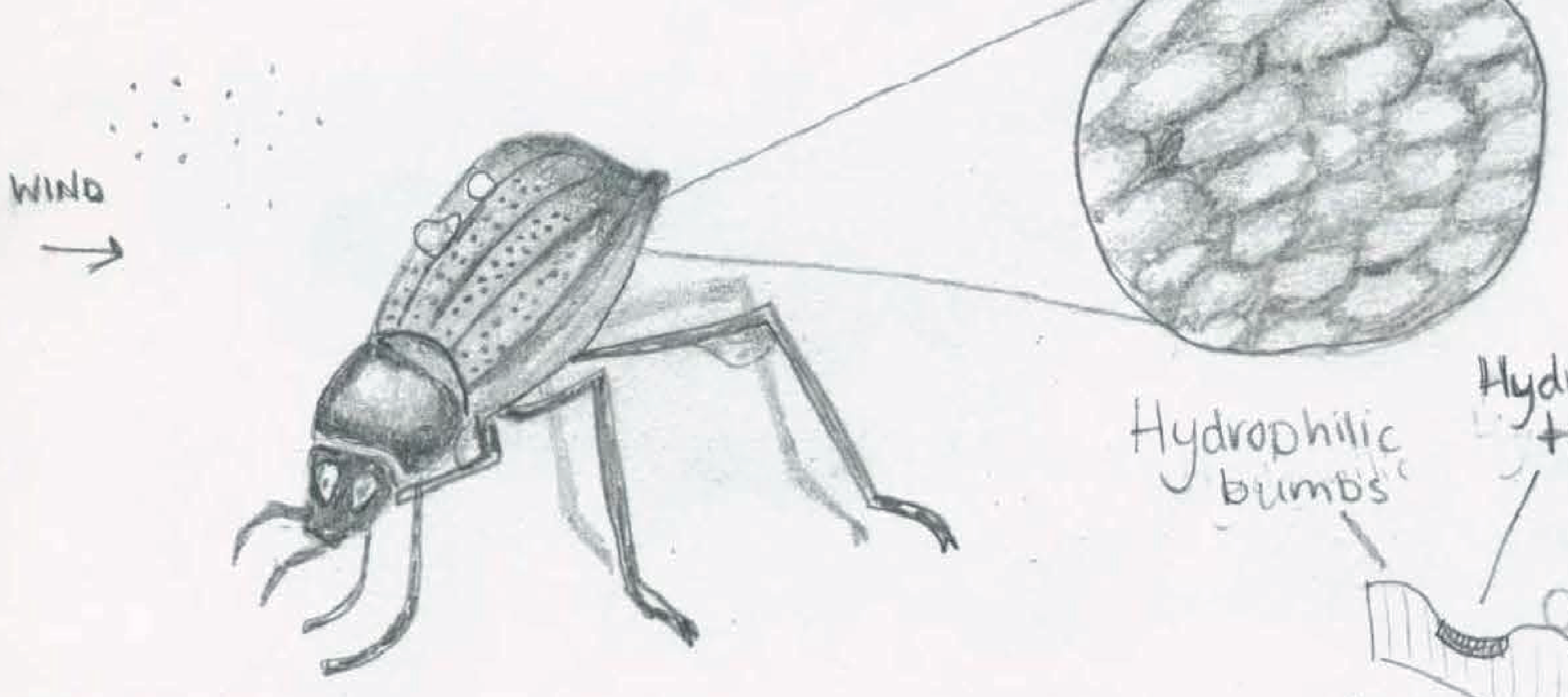
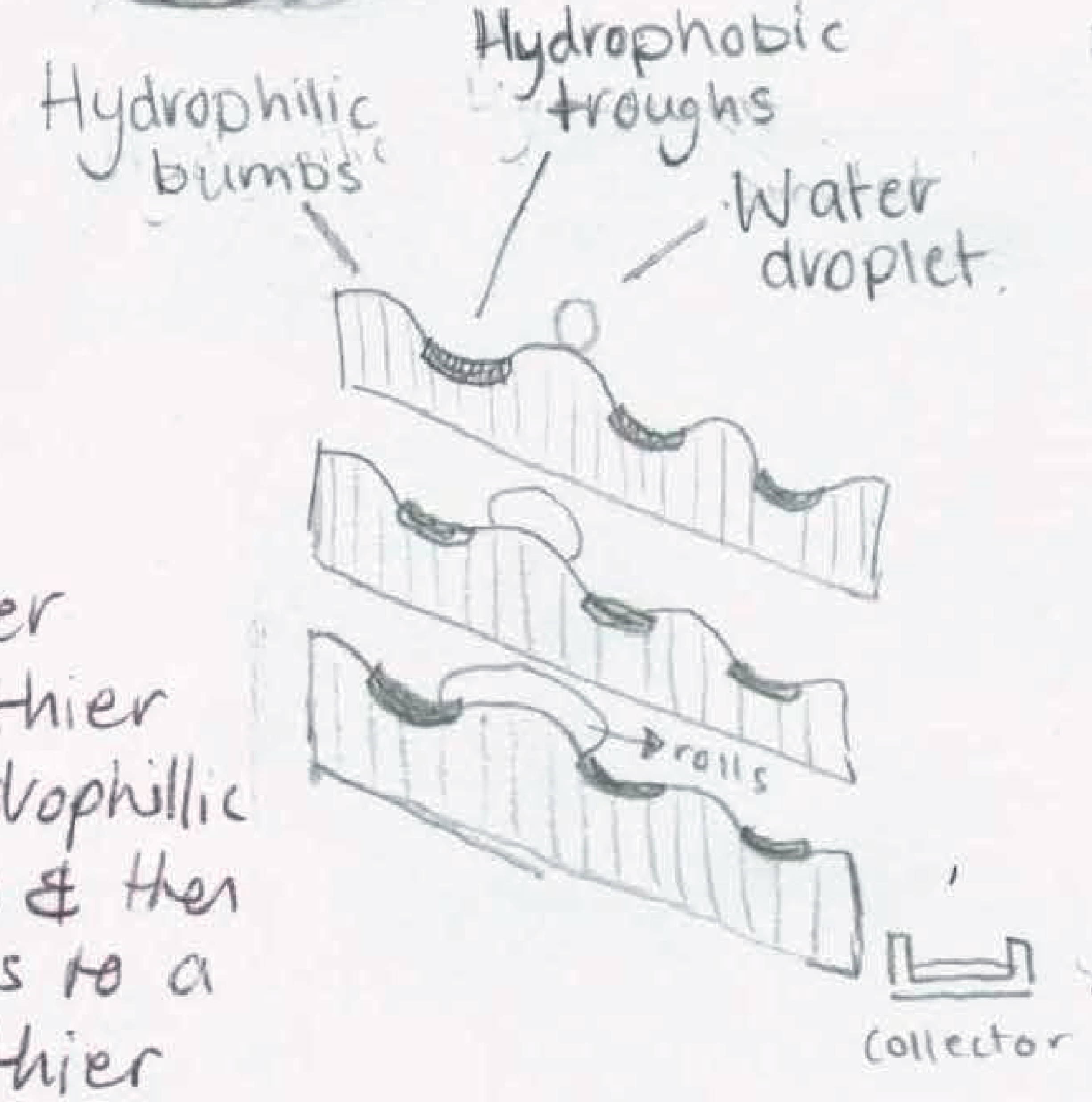
ARTHROPODA

COLEOPTERA

Darkling Beetle



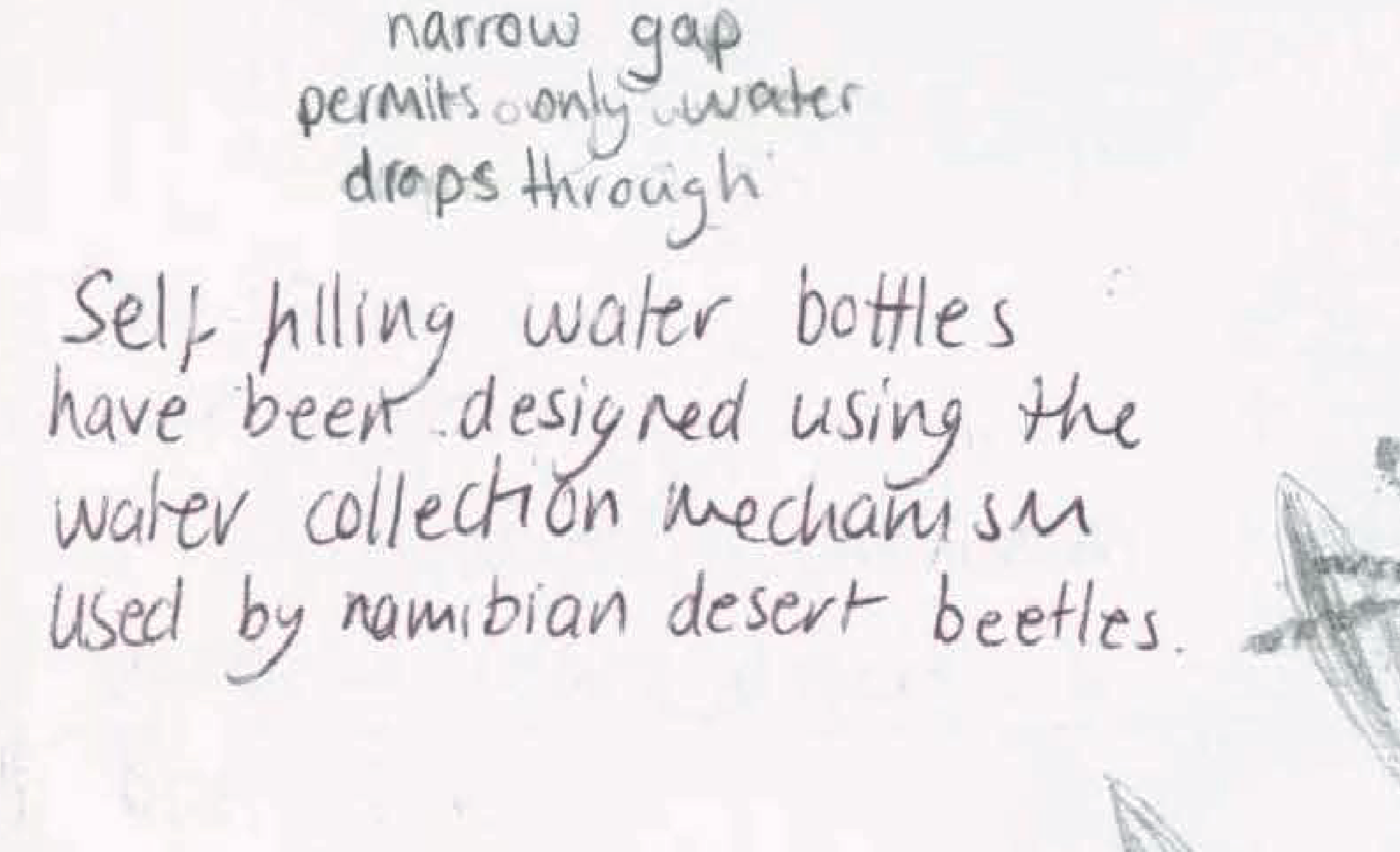


WATER COLLECTION

Namibian desert beetles collect water from mist by facing the wind with thier tails in the air. Water collects on hydrophillic nanobumbs on the beetles exoskeleton & then runs through hydrophobic troughs to a collector which runs straight into thier mouth.

SELF-FILLING

WATER BOTTLES



Self filling water bottles have been designed using the water collection mechanism used by namibian desert beetles.

FOG NETS

Namibian desert beetle inspired fog nets could be used to collect drinking & agricultural water in some of the driest parts of the world

AGRICULTURAL IRRIGATION

ARTHROPODA CHELICERATA Spiders

STRONG SILK

Spiders produce different types of liquid silk in thier silk glands which are released as a gel through spinnerets on thier abdomen. The silk consists of a fibroin core filament covered in other protein adhesives (sericins). The gel is drawn out of the spinnerets as a fine thread stronger than steel & more elastic than latex. The silk also has 'shape memory' & is never soluble in water.

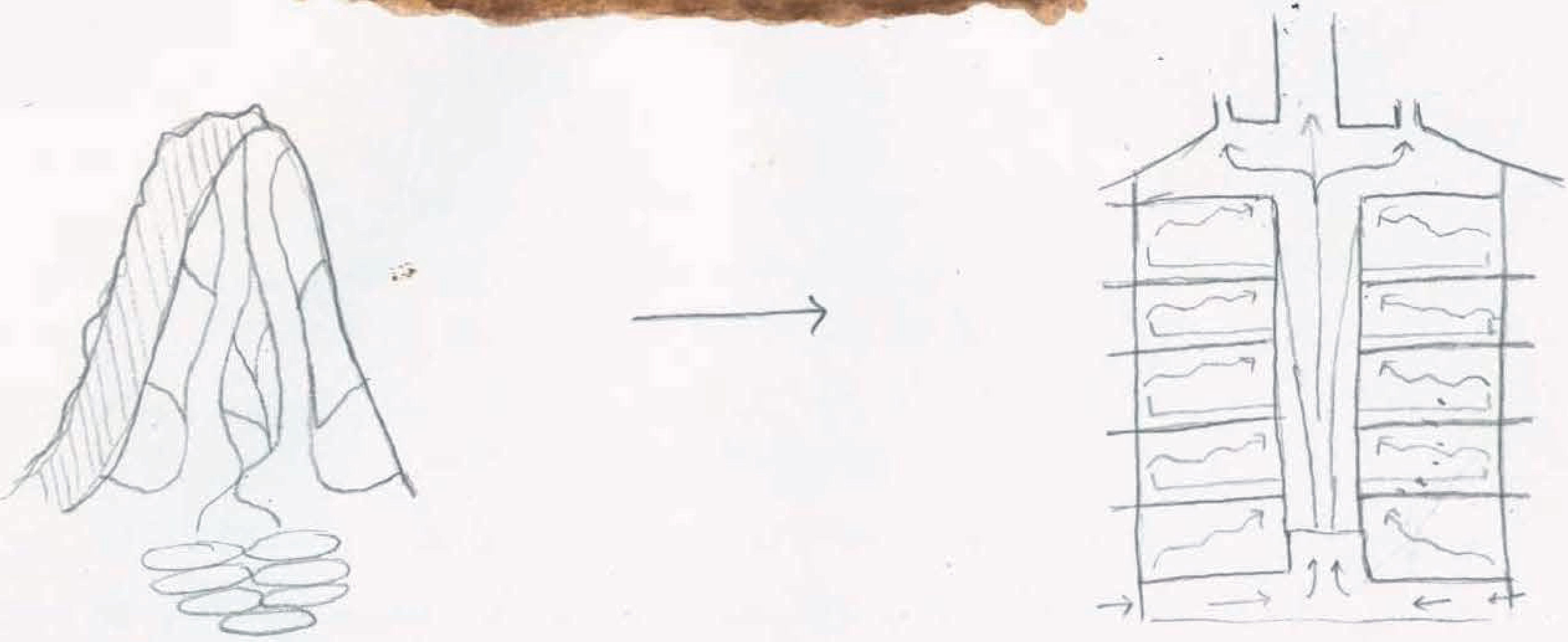
LIGHTWEIGHT MATERIALS

Generating a material which mimics spider silk could have applications in the biomedical domain, for sports or military equipment, or any industry looking for a strong, elastic, ligh weight & benign material.

ARTHROPODA

HEXAPODA

Termites



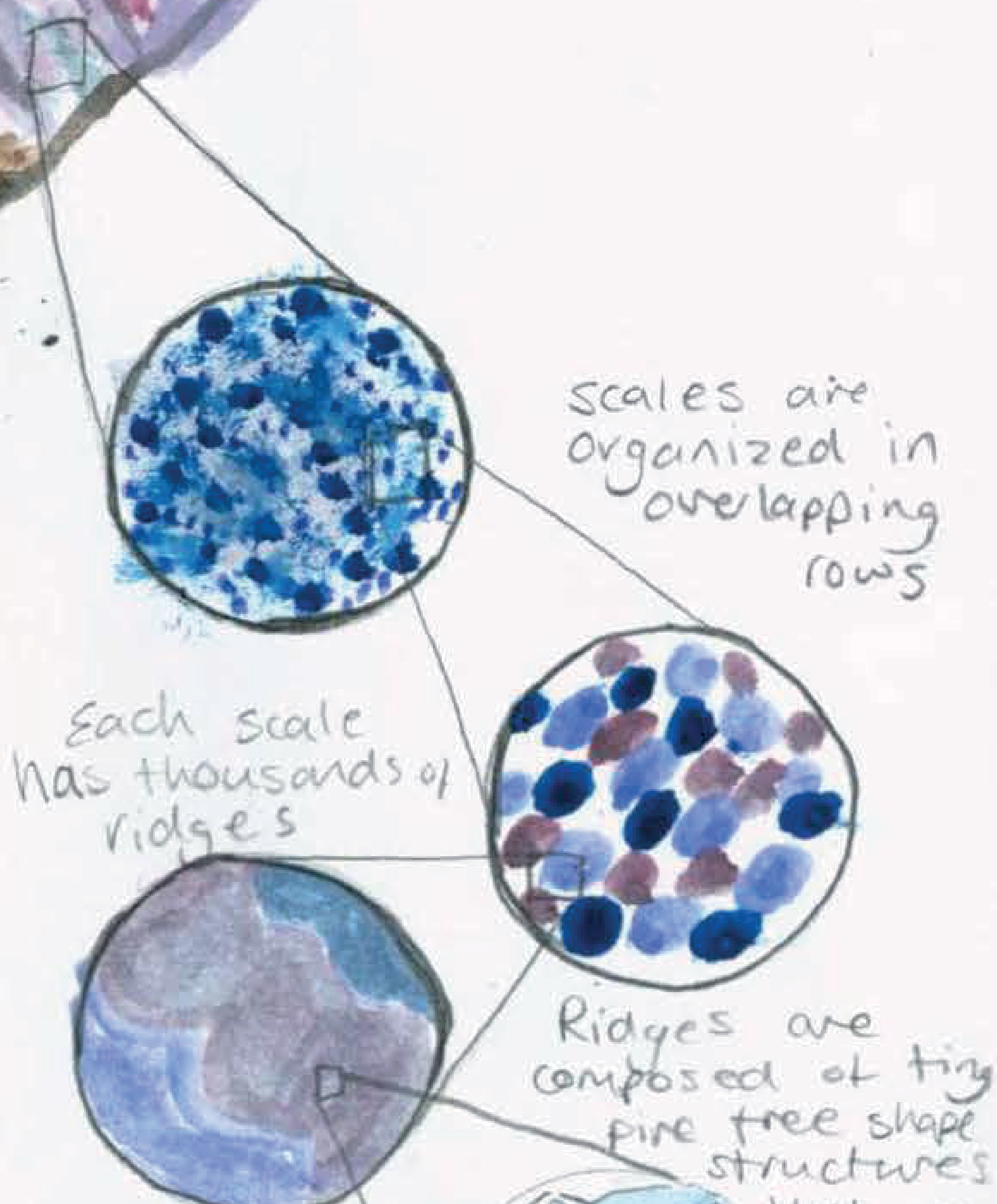
TEMPERATURE REGULATION

Termites can keep thier mounds at a constant temperature of 29°C-32°C despite the outdoor temperature ranging by 40°C. They do this by constructing sophisticated ventillation systems with porous walls & vents which the termites can open & close.

VENTILATION

A termite inspired Eastgate centre was built in Zimbabwe with a self regulating ventillation system with openings that promote passive air flow through high thermal capacity building materials. This mechanism could vastly improve buildings energy efficiency.

ARTHROPODA LEPIDOPTERA Morpho Butterfly



COLOUR EFFECTS

Butterfly wings consist of multi-layered ribbed structures, covered by scales. The colours perceived on the wings are a function of the shape, size & arrangement of the scales. The butterfly wing consists of several strata of pigment & structural scales. which overlap for example, the irridescent blue of morpho butterflies is produced by structural bottom scales & transparent cover scales.

COLOUR & WINDOWS

By mimicing the colour effects of butterflies we could develope materials of any colour without using any pigment, dyes, water or treatment. Furthermore, this could be used to produce spectrally selective glass which could reduce the need for low emmisivity coatings on windows which are usually applied as a seperate material.

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